CHAPTER

4 Mapping Techniques

Documentation

Descriptive Legend

The descriptive legend is the basic document of a soil survey and is composed of four parts: (1) description and classification of the soils, (2) identification legend, (3) conventional and special symbols legend, and (4) general soil map and legend.

Description and classification of the soils.

The descriptive legend includes descriptions of the taxa as they occur in the survey area and descriptions of map units delineated on field sheets. These descriptions form the primary reference document for identifying kinds of soils and miscellaneous areas and provide the information needed for proper classification, correlation, and interpretation. They also provide the information needed to recognize the map units in the survey area. Descriptions of the taxa and the map units, including the ranges in characteristics within the survey area, ensure that all members of the field party classify and map the soils consistently. Creating a clear, concise, accurate, and complete set of descriptions of the soils is a difficult and important job.

An up-to-date record of what has been learned about the soils is especially important when members of a survey party change. If the party leader leaves before completion of the survey area, an up-to-date descriptive legend of how the soils have been classified and mapped ensures continuity in survey operations.

The party leader organizes the information that has been gathered about the soils in an area. While preparing the descriptions, the party leader may discover matters that need clarification or supporting field data. Field studies can then be planned to clarify concepts and improve knowledge of the soils.

Guidelines for describing soils in chapter 3 emphasize individual pedons and polypedons. The soil descriptions in the descriptive legend give the properties of pedons and polypedons plus the extent of the components in each map unit, the variations in properties and in extent of components from one delineation to another throughout the survey area, and the geographic relationships of components within each map unit and of map units to each other. The descriptions are made from detailed descriptions of pedons and polypedons, brief notes about internal properties and surface features, and summaries of transects.

As the descriptions of the soils are prepared, every map unit description is compared with the standard definition of the soil for which it is named and with the descriptions of closely related soils. The classification of the soils must be consistent with the descriptions of the soils in the map units and also with the standard definition of series or other taxa.

A table of classification is included in the descriptive legend and shows how soils in the survey area fit in the national system of soil classification as discussed in *Soil Taxonomy*. Where soil series are used in naming map units, the series can be listed alphabetically followed by the classification, or they can be arranged under the appropriate families, subgroups, and so on.

The nature, kind, position, and amount of inclusions are also described for every map unit. The extent, position, and significant differentiating characteristics of soils that are dissimilar to the major components of the map unit are particularly important. The extent and nature of inclusions that are similar to the major components should also be determined.

Written descriptive records of the soils are references for an ongoing soil survey. The properties of a soil commonly vary from one part of a survey area to another and may be evaluated differently as a result of increased experience in the area.

The soil descriptions are continually revised and updated as mapping progresses. During mapping, new map units and taxonomic units are commonly added and units that are found to be of limited extent are discontinued.

As mapping progresses, kinds of soil are often discovered that do not fit any map units in the legend. If the kind of soil is extensive and uniquely different from the soils in other map units, it is added to the legend after it has been defined by a party member and approved by supervisory soil scientists of the cooperating agencies. Some new kinds of soil can be accommodated best by redefining existing map units, and others can be accommodated as inclusions. New, approved map units must be listed in the legend promptly and defined to enable all members of the party to use them correctly.

Some soils are so limited in extent that they should be included in other map units. Two or more soils that have similar use and management may be best combined in one map unit. Soils that are so closely intermingled that they cannot be delineated separately must be mapped as complexes. Deletions and other changes are not made formally until the supervisory soil scientists have reviewed the proposed legend changes and found them acceptable. If proposed changes are not acceptable, the agency representatives and the party leader resolve any differences they may have. A complete record is kept concerning changes in map units and the disposition of any discontinued map unit. Any changes made between field reviews are recorded in the report of the next field review.

Distinctions between map units must be larger than the ranges that normally occur in measuring diagnostic properties and locating soil boundaries. The soil descriptions must be tested to ensure that the map units are recognized and delineated consistently.

Progressive mapping by the field party is a continuing test of the legend. Inadequacies are evaluated, and any necessary changes are made in the legend. Changes are recorded on all copies of the legend, and each soil scientist in the party must clearly understand the new concepts.

Field notes are summarized periodically and the summary is recorded in the revisions of the soil descriptive legend. If observations are not summarized and recorded promptly, they may be lost or not used by other members of the survey party.

Field reviews also test the legend and its use in mapping to determine whether survey objectives and requirements are being met. Such reviews usually involve supervisory soil scientists and representatives of cooperating agencies.

The final test of a descriptive legend comes during the formal steps in soil correlation. Correlation is a continuing process from the initial descriptions before mapping starts to the final correlation. A map unit can be tentatively correlated as soon as it has been accurately described and mapped. Few changes are needed in final correlation if the descriptions are adequately tested and revised as the survey progresses.

Quality soil descriptions ensure a quality soil survey. The importance of soil descriptions cannot be overemphasized. A good set of descriptions is needed for consistent, uniform, and accurate mapping. The descriptions also provide the basic information needed for complete and accurate interpretation. Working from the soil descriptions, supervisory soil scientists can give maximum help to the survey party.

Soil surveys of lesser detail, made with more widely spaced field observations, traverses, or transects, resemble the preliminary surveys made to prepare the initial set of soil descriptions for detailed mapping. For these surveys also, map unit descriptions are modified as more is learned about the soils. Map units are added only after they have been defined and approved by the representatives of the cooperating agencies.

Identification legend.—A symbol is placed in each delineation on the map to identify it. The identification legend is a list of these symbols and the names of the map units they represent. In some legends the names of the map units are listed alphabetically, followed by their symbols. This list of names is used by soil scientists as they map. In other legends the symbols are listed in order, followed by their names. This list is used by everyone who reads the maps. Usually both lists are prepared. If the symbols are not listed in order, as is common when new map units are added to the legend, associating a symbol on the map with the map unit it represents can be difficult.

The identification legend keys names of map units to delineations on the soil maps through the map unit symbols. Many conventions and systems are used for selecting symbols. The choice of symbols is unimportant provided the symbols are short, each symbol is unique, and the map unit that each symbol represents is named and described.

All symbols must be legible on photographic reproductions of the maps. Long symbols are difficult to place on the map without being made too small to be legible. Long symbols often must be placed outside small delineations and arrowed into them. This increases the chance of error. Experience and tests have shown that map users have great difficulty in reading field sheets that have many symbols placed outside the areas to which they apply. If the symbol is arrowed from a large delineation to a small one, many users assume that it represents the large delineation.

The map symbols serve primarily to identify map units; any connotations of soil properties are incidental. Efforts to go beyond identification and devise connotative symbols usually leads to a legend that fails to achieve its primary purpose. The connotative value of symbols may be offset by decreased legibility of the map. Map users must not assume that connotative symbols or even the map unit names describe all of the important soil properties. The set of soil descriptions (map unit and taxon descriptions) is essential to the purpose of the soil survey and should be used by mappers and by those who need the information while the survey is in progress.

Using the same or similar symbols during the mapping process and on published maps accelerates map compilation because compilers are not required to spend much time converting one set of symbols to another. Errors are reduced. Such symbols have the greatest advantage in areas where soils are well known. Where soils are not well known at the start of the survey, changes during mapping and correlation may reduce the advantages.

The following are parts of two identification legends.

Map symbol	**Map unit name**
AdA	Allendale loamy fine sand, 0 to 3 percent slopes
Ax	Angelica silt loam
Ba	Bach silt loam
Bn	Bonduel loam
Bo	Borosaprists
BrB	Boyer loamy sand, 1 to 6 percent slopes
BrC	Boyer loamy sand, 6 to 12 percent slopes
BrE	Boyer loamy sand, 20 to 35 percent slopes
Ca	Carbondale muck
CbA	Casco sandy loam, 0 to 2 percent slopes
CbB	Casco sandy loam, 2 to 6 percent slopes
CbC2	Casco sandy loam, 6 to 12 percent slopes, eroded
CdB	Casco-Rodman complex, 2 to 6 percent slopes
1	Almota silt loam, 7 to 25 percent slopes
2	Almota silt loam, 25 to 65 percent slopes
3	Alpowa cobbly silt loam, 30 to 65 percent slopes
4	Anders silt loam, 3 to 15 percent slopes
5	Anders-Kuhl complex, 3 to 15 percent slopes
6	Asotin silt loam, 7 to 25 percent slopes
7	Asotin silt loam, 25 to 65 percent slopes
8	Athena silt loam, 3 to 7 percent slopes
9	Athena silt loam, 7 to 25 percent slopes
10	Athena silt loam, 7 to 25 percent slopes, eroded
11	Athena silt loam, 25 to 40 percent slopes
12	Athena silt loam, 25 to 40 percent slopes, eroded
13	Athena silt loam, 40 to 55 percent slopes
14	Bakeoven-Tucannon complex, 0 to 30 percent slopes

Conventional and special symbols legend.—Conventional symbols on soil maps show many natural and cultural features other than map units and their boundaries. They help users locate delineations. Special symbols identify some areas of soils or miscellaneous areas that are too small to be delineated at the scale of mapping. All symbols must be defined. Definitions of special symbols specify the size of area that each represents.

General soil map and legend.— The general soil map helps the field party in mapping and in organizing field work. The draft of the general soil map prepared during preliminary field studies is refined as more is learned about the soils. The properties, distribution, and extent of the soils in each general area and their suitabilities, limitations, and potentials are described. Significant differences in soil moisture or soil temperature between areas can also be shown on the general soil map.

Soil Handbook

The descriptive legend is the main document that governs field operations, but it is only part of the information compiled during a survey. The descriptive legend and the other information about the soils in the survey area are organized into a soil handbook. The soil handbook is used by the field party and by engineers, agronomists, planners, and others who need information about the soils of the area before the survey is completed.

The handbook contains everything needed for the published soil survey, plus material that is important to the soil scientists who are making the survey. A detailed outline for the text of the published soil survey should guide development of the handbook.

Included in a soil handbook, in addition to the mapping legend are interpretations and general sections covering such topics as climate, physiography, relief, drainage, geology, and vegetation, which relate to the kinds of soil in the area. These characteristics improve the understanding of the properties, distribution, use, and management of the soils.

In addition, a record of the acreage of each map unit is maintained. In some surveys acreage is recorded progressively as the field sheets are completed. In other surveys progressive acreage records of each map unit are kept only until the unit is found to be extensive enough to keep in the legend. The final tally is made after the survey has been completed.

Some items prepared for the mapping legend or handbook may be incorporated into different sections in the publication. For example, the genetic key and classification table could become part of the section on how the soils formed and how they are classified. Some of the diagrams could be used in that section as well as in the section on the general soil map.

The descriptive legend and soil handbook should follow the same format that will be used in the published soil survey. A soil handbook that is kept up-to-date as mapping progresses will require a minimum amount of editing after the mapping has been completed.

Supporting Data

Data collected can be filed in the soil handbook. Separate sections can be added that contain all additional documentation obtained during the course of the survey. In addition, file folders, cross-indexed by soil series and map unit, can be used. Items that require simple filing systems for easy retrieval are transects, field notes, soil keys, laboratory data, special studies, special interpretations, climatic data, geology maps, vegetation maps, research reports, and any other items unique to the survey. A few of these are described below.

A *genetic key* shows the relationships of the various taxa to factors such as parent material, natural drainage, vegetation, annual precipitation, topographic position, and form, and aspects. The key should emphasize the factors associated with important soil characteristics and differences in characteristics within the survey area.

A *table of soil characteristics* highlights important properties of the soils. Comparisons can be made easily and quickly. Both the genetic key and the table of soil characteristics are particularly helpful in orienting newly assigned field personnel.

The *general soil map* helps the field party in mapping and in organizing field work. The draft of the general soil map that is prepared during preliminary field studies is refined as more is learned about the soils. The properties, distribution, and extent of the soils in each general area and their suitabilities, limitations, and potentials are described. Significant differences in soil moisture or soil temperature between areas can also be shown on the general soil map.

Remotely sensed imagery is produced from both photographic and nonphotographic sensors. The use of more than one set of imagery for reference is important. Several sets of photographs and other images are likely to yield more clues about soils than one set. The kinds of remote imagery and their advantages and disadvantages in soil mapping are discussed later in this chapter.

Photographs of soil profiles can be very effective in illustrating some soil features. Photographs or diagrams of landscapes show the relationships of soils to various landscapes. Cross-sectional and three-dimensional diagrams of parts of the survey area are also helpful.

Notes are indispensable parts of the mapping legend. Some notes are used in revising the descriptive legend, which becomes incorporated in the manuscript for publication. Notes help make mapping faster and more accurate. They may record tonal patterns on aerial photographs that are peculiar to a certain map unit, the relationship between minor but key indicator plants, or the surface configurations that have little bearing on use or management but that help the mapper locate significant soil areas. Notes and other information needed in mapping but not intended for publication can be kept on separate sheets after each taxon or map unit description in the descriptive legend.

Maps

Imagery to Aid Field Operations

Aerial photographs are used as the mapping base in most soil survey areas in the United States today.[1] With few exceptions aerial photographs are by far the most practical mapping base for field use by soil scientists. Several kinds of aerial photography are available. Conventional panchromatic (black and white) photography is sensitive to approximately the visible portion of the electromagnetic spectrum (wavelengths of 0.38 to 0.78 micrometer). Color photography covers a similar range. Infrared photography, which covers radiation of somewhat longer wavelengths, is also available. The main kinds of aerial photography are described in the following paragraphs.

Single-lens aerial photographs.—The two basic types of aerial photographs are vertical and oblique. Single-lens vertical photographs are the best for soil mapping, although oblique or multiple-lens photographs can be used when rectified. USDA specifications for single-lens aerial photography require an overlap in line of flight of about 60 percent and a sidelap between adjacent flight lines of an average of 30 percent. With this overlap, all ground images appear on two or more photographs exposed from different air positions, providing *stereographic coverage*. Two consecutive photographs within a line of flight are called a *stereographic pair*.

If every other photograph in a continuous line of flight is removed, the remaining photographs provide *alternate coverage*. Adjoining photographs of alternate coverage in the same line of flight are called *alternate pairs*. Alternative pairs overlap about 20 percent—too little to permit stereoscopic study of the entire area. Using alternate coverage, instead of full stereographic coverage for mapping, leads to problems with relief displacement during map

[1] Details on procedures and techniques in the use or aerial photographs in soil surveys is provided in Agriculture Handbook 294, "Aerial-Photo Interpretations in Classifying and Mapping Soils." SCS, USDA, 1996.

compilation. Alternate coverage is inadequate for constructing maps by photogrammetric methods based on complete stereographic coverage.

Photographs are exposed on film at a predetermined scale and fixed negative size. The scale depends on purpose. Most USDA aerial photographs are taken with a 153 millimeter lens. Scale ranges from 1:38,000 to 1:80,000. Satisfactory enlargements up to 1:7,920 can be made from 1:40,000 negatives. Most aerial cameras currently in use expose an image of about 23 by 23 centimeters.

Photographs made directly from the original negatives at the same scale are called contact prints. In contact printing, errors cannot be rectified and the scale cannot be changed. Contact prints are economical to make and have better resolution than enlargements.

Photographs can be readily enlarged or reduced; this is one of their advantages. The process is slower and more expensive than contact printing. Some detail is lost in the preparation of enlargements, but the loss is small when skilled operators use modern processing equipment and the original negatives.

Enlarging has certain advantages. All prints for an area can be brought to a nearly uniform scale. Tilt, which causes displacement of objects and scale distortion, can be rectified. Such operations require more time than simple enlarging, but later savings may more than offset the cost of bringing photographs to a common scale. If the photograph is enlarged more than 5 times, prints are usually unsatisfactory. Enlargement increases the size of the photograph as well as the scale. The size of sheet varies with the enlargement. If the contact print at a scale of 1:20,000 is 23 cm square, an enlargement to 1:15,840 will be 29 cm square and an enlargement to 1:7,920 will be 58 cm square.

Photo indexes are inexpensive and should be obtained when available. They are useful for determining the number and location of individual photographs within an area. They are also useful for schematic mapping and for preliminary studies.

The greatest advantage of aerial photography in soil surveying is the wealth of ground detail shown. Field boundaries, isolated trees, small clumps of bushes, rock outcrops, and buildings are visible and assist in orienting the mapper and in plotting the soil boundaries and other features. Both the speed and accuracy of the work are increased by using photographs. Base maps for publication can be constructed from aerial photographs economically and in a reasonable time. Showing all of the intricate cultural and physical details, a stereographic series provides a relief model of the area.

Aerial photographs also have some disadvantages and limitations in soil surveying. Elevations are not shown. Scale is not precisely uniform. Differences of scale between adjoining photographs create some minor difficulties in matching and transferring soil boundaries. Distances and directions cannot be measured as accurately as on topographic maps or some other kinds of photographs because of distortions caused by tilt, image displacement, and other inherent errors. Finally, although far more detail is shown on aerial photographs than on most maps, the detail is not always as legible and more skill is required to interpret the photograph. Nevertheless, the advantages of aerial photographs generally greatly outweigh the limitations.

Photographic indexes are available for most of the photography available from Federal agencies. Indexes are prepared by fastening together the individual prints of an area. The images are matched, and the photographs are overlapped so that all marginal data are visible. The assembly is then photographed at a smaller scale. Most indexes prepared by the United States Department of Agriculture have a scale of 1:63,360 or 1:126,720.

Once a survey has been scheduled, photographs should be ordered as soon as possible. The order gives the exact boundaries of the survey area, the scale of photography needed, desired coverage (stereographic or alternate), and the date that fieldwork is to begin. Any special requirements, such as weight or finish of paper, are stated. Low-shrink paper is recommended for most field-mapping.

Panchromatic photography records all colors in varying shades of gray. Most modern black and white photography is of excellent quality. Because of their quality and economy, photographs made from panchromatic film are the most widely used for soil surveys.

Color photography records features of the surface in colors of the visible spectrum. The colors on the print are about the same as the colors of the features when the photograph was taken, but the colors of the ground features may be different at other times. The color of a soil also may differ, according to such factors as sun angle, atmospheric conditions, delays between flights, and moisture state of the surface. The cost for obtaining color photography is about 11/2 to 2 times as much as panchromatic photography. Color prints cost 2 1/2 to 4 times as much as black and white prints. Excellent black and white prints can be made directly from color negatives at the same cost as prints from a panchromatic film.

With high-altitude photography, fewer photographs are required to cover an area. Contact prints of the original negatives can be used for stereographic coverage. Enlarged stereographic coverage can be prepared from selected stereographic pairs. Special stereoscopes are helpful when viewing the larger prints in field offices.

For some soil surveys, photobase maps are printed from high-altitude photography and low-shrink paper. In other surveys the photobase maps are printed on transparent film with a matte surface. Normally, field mapping on outdated photographs is transferred to film prints, and paper prints are used for new field mapping.[2]

Obtaining high-altitude photography and preparing photobase maps nearly always cost less than constructing photobase maps from a controlled aerial mosaic. High-altitude photographs have better image quality than controlled mosaic ones.

Infrared photography records a portion of the spectrum that is not visible to the human eye. Infrared film is also sensitive to part of the visible spectrum, but true infrared photography is exposed through a deep red filter so that only the infrared radiation is recorded. Prints from infrared film have distorted shades of gray in comparison to prints from panchromatic film. Bodies of water and areas in shadow appear black. Broad-leaved trees appear very light, as though covered with frost. Foliage of coniferous trees appears distinctly darker. Roads are dark, instead of very light as on panchromatic prints. These characteristics are useful for detecting patterns of soil moisture states, identifying forest types, and detecting vegetation under stress from disease or other causes. Infrared aerial photography is especially valuable in areas having atmospheric haze because the film is not sensitive to the blue portion of the spectrum that is normally associated with haze. Infrared photography costs about 10 percent more than panchromatic photography.

Modified infrared photography is a compromise between true infrared photography and panchromatic photography. The images have some of the characteristics of each. At first glance,

---

[2] More detailed information about cartographic techniques and requirements for photobase maps are given in the "Guide for Soil Map Compilation on Photobase Map Sheets" (Cartographic Division, SCS, USDA, 1970 Photobase maps can also be prepared in a similar form from the controlled mosaics or other suitable photography.

a modified infrared photograph looks very much like a photograph made from panchromatic film. It shows more contrast between some kinds of vegetation and records differences in soil wetness in more distinctive patterns than panchromatic photographs. Modified infrared photography costs about 10 percent more than panchromatic photography. Prints from infrared negatives cost the same as prints from panchromatic film.

Color infrared photography is sensitive to the green, red, and infrared portions of the electromagnetic spectrum. It produces false colors for most objects. The prints are spectacular; the colors are often brilliant and contrasting. This type of photography is especially useful for the study of vegetation. Vigorously growing vegetation appears brilliant red. Color infrared photography costs about the same as conventional color photography.

Remote sensing.—refers to the full range of activities that collects information from a distance. It includes photography, which has been the most widely used remote sensing technique for many years. The range of the electromagnetic spectrum that can be sensed from a distance, however, is much greater than that covered by conventional photography. Other techniques have been devised to use part of this range.[3] Nonphotographic sensors can perceive the parts of the electromagnetic spectrum from ultraviolet (wavelengths less than 0.38 micrometers) through microwave to the upper wavelength of 100 cm.

The extent to which some of the newer remote sensing techniques can be used in soil surveys has not been fully explored. Field work cannot be eliminated, but how much it can be reduced is not clear. Soils must be examined to a depth of about 2 m or to solid rock—beyond the present reach of most remote sensors or combination of sensors. At least some clues to many soil properties are provided by surface features. It is these clues, many of them quite subtle and obscure, that are sought and used in drawing soil boundaries. These clues also assist the making of accurate soil maps without excessive digging or probing. Remote sensing contributes greatly to soil surveys by revealing these clues. The imagery extends hard data about soils and their formation to new areas.

In areas of the country where it can be used, ground penetrating radar (GPR) and statistical analysis of the radar data can be a useful aid to soil mapping and can provide an effective and efficient method to characterize variability within soil map units. GPR has the advantage of observing a linear transect of the soil continuum across a landscape.

The prospect of using more than one set of imagery is important. Such a set might be made up of two or more kinds of photography made at the same time—multiband photography—or two sets of one kind of photography made at different times of the year, or some combination of these. Although several sets of photographs and other imagery are likely to yield more clues about soils than one set, the extra cost for the additional clues would have to be justified.

Photograph-like images can be made by nonphotographic sensors of any part of the electromagnetic spectrum. Hence, outputs from the sensors can be viewed and treated like photographs. An example is *side-looking radar*, which can penetrate clouds and can be used at night as well as in the daytime. The radar can produce prints that resemble photographs, although the images are not as clear as panchromatic photographs. Side-looking radar is useful where continuing cloud cover prevents conventional photography. For use with computers, impulses

---

[3] Remote Sensing: "With Special Reference to Agriculture and Forestry." Committee on Remote Sensing for Agricultural Purposes, Agricultural Board, National Research Council, Washington, D.C. National Academy of Sciences, 1970.

from side-looking radar and other nonphotographic sensors can go directly into automatic data processing systems for storage or analysis.

Space exploration has added a new dimension to remote sensing. Earth-orbiting satellites can be equipped with several kinds of sensors, including cameras. Imaging from space has the same problems as imaging from aircraft and the additional problem of transmitting the data to earth. Imaging from space has two important advantages. First, large areas&$151;thousands of square kilometers—can be examined from a single point in orbit. Second, any area can be repeatedly examined on a regular schedule.

Base Material

More than one kind of cartographic material suitable as a mapping base could be available for an area. The choice of base material depends on the relative advantages of available material for all aspects of the job, including map compilation and reproduction as well as fieldwork.

Selecting the mapping base.—The quality of the cartographic material used in mapping and for publication affects the accuracy of map unit boundaries and soil identification, the rate of progress, the methods and costs of map construction, and the quality of the published map. The assembly of cartographic materials should begin as soon as an area is selected for survey.

For most surveys, purchasing new or recent photography and preparing field sheets at the dimension and scale that will be used for publication is an economically sound practice. Some of the costly steps of map compilation are eliminated. High-altitude aerial photographs are particularly suitable, as are orthophotographs. Such photography is precise enough to eliminate the preparation of a costly controlled mosaic.

Plans for the survey must consider all costs of map construction—fieldwork, compilation, finishing, and publication. Plans must be made in advance of field operations, especially if contracts are to be let for new photography. Completion of aerial photography contracts can be delayed for a long time by adverse weather conditions.

In ordering new photography, time must be allowed for preparing specifications, awarding contracts, photographing the area, and inspecting before accepting the work. The cost of original aerial photography varies greatly.

Enabling aerial photography contractors to keep their equipment and personnel busy throughout the year and taking advantage of favorable seasonal conditions reduces the cost of aerial photography. Such factors as geographic latitude and solar altitude must be considered in scheduling flights to reduce or eliminate objectionable shadows. Trees should be bare and other vegetation at a minimum for the best results. This requirement further limits the flying season in the northern half of the United States. Moisture conditions are important in revealing soil patterns. In areas of the central United States where annual row crops are the main type of crop, the lack of ground cover and soil-moisture conditions are nearly optimum for indicating soil pattern sometime between late April and the end of June. For economy, scheduling requires close study of regional weather patterns in a survey area in order to forecast the number of "photographic days" (no more than 10 percent cloud cover) in each month.

Orthophotographs.—An orthophotograph is an aerial photograph with nearly all the image displacement and scale errors removed. Aerial photographs are converted to orthophotographs by simple rectification for low-relief terrain or by differential rectification for high-relief terrain. Orthophotography is prepared by methods designed to meet National Map Accuracy Standards. Various accuracy tests are performed to verify that 90 percent of the well-defined points tested are within 12.19 meters of true horizontal position—the horizontal accuracy standards for a 1:24,000 scale. An *orthophotoquad* is an orthophotograph formatted to the same size and scale as any of the USGS topographic quadrangles.

Orthophotographs portray an abundance of detail and have correct scale and positional accuracy that is not found in conventional aerial photography. Production costs of orthophotographs compare favorably with controlled mosaic production costs. Orthophotographs of varying scales are used as base maps for soil surveys, land-use planning, resource studies, and topographic maps. Orthophotography can be enhanced with such cartographic features as contours, political boundaries, highways, and principal places to provide maps designed to meet the general need of most users.

Aerial mosaics.—Aerial mosaics are made by matching and assembling individual photographs to form a continuous image of an area. Several methods of assembly are used, and the resulting mosaics vary widely in accuracy and usefulness.

The two general types of aerial mosaics are uncontrolled and controlled. An *uncontrolled mosaic* is made by simply matching like images on adjoining photographs without geographic control of the positions of the features. A *controlled mosaic*, displays photographs that are very close to uniform scale and rectified to reduce tilt and displacement. Features on the mosaic are close to their correct positions on the map grid. The accuracy of a controlled mosaic approaches that of a good planimetric map.

Between the uncontrolled mosaic and the controlled mosaic are a wide variety of semicontrolled mosaics for which different degrees of ground control are used. Mosaics vary greatly in accuracy and must be carefully checked before being used in soil mapping.

Because an aerial mosaic covers a larger area than a single photograph, fewer photobase sheets need be matched and the chance for error is reduced. A mosaic can be made to cover a specific area, such as a township or a drainage basin.

Topographic maps.—Topographic maps are not photographs. A topographic map represents horizontal and vertical positions of physical features by using standard symbols. Published maps usually show cultural features such as roads, railroads, and buildings in black; drainage features in blue; and contour lines in brown. Some also show additional features, such as vegetation in overprints of green or other colors.

Most topographic maps published by the U.S. Geological Survey and other Federal agencies comply with national standards of map accuracy. The standards for horizontal accuracy require that not more than 10 percent of the tested points be in error by more than a specified distance on the map. This distance is 0.85 mm for maps published at scales larger than 1:20,000 and 0.50 mm for maps published at 1:20,000 or smaller. These limits apply to positions of such well-defined points as roads, monuments, large structures, and railroads that are readily visible and can be plotted on the map within 0.25 mm of their true positions. Standards for vertical accuracy require that not more than 10 percent of the tested elevations be in error by more than one-half of the contour interval.

Because of the prescribed standards of accuracy, topographic maps published by different agencies differ little. Some variation may be noted in format, scales, sheet boundaries, and classification and selection of planimetric detail—variations due primarily to the need to meet specific requirements.

Standard topographic maps are published in quadrangles bounded by lines of latitude and longitude. Generally, topographic quadrangles cover 30 minutes, 15 minutes, 7 1/2 minutes, or 3 3/4 minutes of latitude and longitude. Scale varies with topography and contour interval. The most common publication scales are 1:24,000 (the largest generally available), 1:25,000, 1:31,680, 1:48,000, 1:62,500, and 1:63,360. Coverage at 1:250,000 compiled from larger scale maps is distributed by the Geological Survey for the entire country, and a new series of maps at scales of 1:50,000 and 1:100,000 is available for certain areas. The smaller scale maps are useful as the bases for general soil maps, for reference, and for schematic soil maps. Topographic maps can be used as the base for detailed mapping if recent large-scale maps are available for the whole survey area.

The accuracy of standard topographic maps gives them definite advantages in measuring distances and directions. The topographic pattern is helpful in understanding soil and studying drainage, irrigation, and hydrology. The detail on the maps relieves soil scientists of part of the task of recording the location of ground features while mapping.

As a base for soil mapping, topographic quadrangles lack the details—field boundaries, isolated trees and bushes, fences, and similar features—that are shown on photographs. The small scale of many topographic maps is a disadvantage. The topographic maps of recent years made from aerial photographs by photogrammetric methods are much more accurate than old topographic maps which may not be accurate and may need too many revisions to be useful.

In the United States, most standard topographic maps are published by the U.S. Geological Survey. The cartographic staffs of the Soil Conservation Service receive new lists and new quadrangles as they are published and can supply information about work in progress, expected dates of completion, and the topographic mapping program. Topographic maps needed for a soil survey can be ordered directly from the Geological Survey. Preliminary proofs or copies of manuscript material frequently can be obtained in advance of publication if the need is urgent.

Topographic maps of standard accuracy are expensive to construct and publish, but the published maps can be purchased for a small price per sheet. Besides serving as the mapping base in some areas, they are useful references.

Maps and data-base requirements.—The demand for natural resource data in SCS and the Federal sector has increased. In the past these data were displayed on various base maps that generally did not meet national map accuracy standards. Soil Conservation Service could not feasibly digitize the resource data because the use by SCS and other agencies is limited by the inaccurate bases being used. Using accurate uniform scale orthophotographs and planimetric base maps, resource data will be digitized and available for automated mapping procedures and repeated manipulation in providing various inventories and interpretative maps at great cost reduction. Repeatability of use of digitized data by SCS and other agencies, including exchanging of digitized resource data by agencies, precludes a duplication of effort in the Federal sector and results in savings in Federal mapping programs.

Selecting Mapping Scale

The best map scale for a survey is determined by many factors. The purposes of the map are the main consideration. Soil maps in areas of intensive land uses are designed for predictions about soil use, management, and behavior in relatively small areas. The scale must be large enough to permit delineation of most areas significant for such predictions. The scale does not have to be large enough to include all property lines, cultural features, works, and structures for detailed plans to be plotted directly. A large scale increases the number of map sheets, the amount of joining of sheets, and the cost of compilation, reproduction, publication, and storage.

Most soil surveys are made at a scale of 1:24,000 or 1:12,000. A scale of 1:24,000 commonly is used for surveys in areas of less intensive land use. Scales of 1:12,000 are needed for highly detailed surveys.

Generally, the scale of mapping depends on the intricacy of the soil pattern in relation to the expected intensity of soil use. The patterns of soils are very complex in many areas where potentials do not justify a mapping scale large enough to show the patterns in detail. Where the purposes of the survey do require that small areas be delineated, the scale must be large enough to permit delineating and labeling the areas. Part of a survey area may have high value or intensive land use that justifies a scale larger than that of the rest of the area. Two publication scales can be used in such an area if the needs justify the extra costs.

Legibility of the maps is very important. Many potential users will not use maps that they can not read easily. Figure 2-4 illustrates differing legibility of the same map at different scales. Map C is clearly illegible. Map B can be read with difficulty. Map A is reasonably legible. If the map is to be published at scale B, detail that is legible only at scale A should not be delineated.

Table 2-2 gives a general idea of the smallest areas that can be shown legibly at different scales. These sizes are for isolated areas within much larger delineations. If numerous intermingled areas of the smallest size are delineated, the map will be difficult to use.

If the field sheets are made at the planned publication scale, the amount of detail that should be drawn in the field is limited to that judged adequate for the purposes of the published survey. Using the publication scale also eliminates the necessity of transferring the field mapping to a different scale. If mapping scale is larger than publication scale, the surveyor should try to visualize what the map will look like at publication scale. A reducing lens can be used.

Reference Maps

Many types of maps are published by public and private agencies. They range from small-scale road maps prepared by oil companies and county highway maps prepared by State highway departments to the large-scale detailed maps used in city planning.

Most reference maps are designed, constructed, and reproduced to meet a special purpose. Necessary details are emphasized and others are subordinated. On small-scale road maps, for example, highways, highway numbers, towns and cities, points of interest, and mileages are prominently shown; drainage, railroads, pipelines, powerlines, and public land lines are omitted or subordinated.

Aeronautical charts.—These are designed and constructed specifically for air navigation. The scale is small so that large areas can be shown on a single sheet. Ground features that are prominent from the air are emphasized in bold and simple symbols. Other features of equal importance on the ground but less noticeable from the air are subdued or omitted entirely. Elevation is shown by gradient tints. Navigational data are shown by bright overprinting.

Plats.—These are prepared from public land surveys and are designed to present land survey data. They usually cover a survey unit, such as a township. The scale is large. Courses remote areas. Aeronautical charts, for example, are useful for rapid small-scale surveys of large areas.

Many other kinds of special maps are available for some areas. These include maps of published soil surveys, maps of geology, maps of forest or other vegetative cover, coast and harbor charts, census maps, U.S. Postal Service maps, and highway maps. County highway planning maps are available for many areas and are good references. Some State highway or transportation departments make good small- to medium-scale highway planning maps for internal use that can be reproduced with special permission. Maps protected by copyright cannot be reproduced without permission.

Index Maps for Field Sheets

An index map is prepared to show approximately the location of each field sheet. A useful scale is about 1:125,000. Many States have county highway maps at about this scale, and many of these are good bases for preparing the index.

The mapping limits of each field sheet are drawn on the index map, and the field sheet number is written in each area. The preferred position for the label—"Index to Field Sheets"—is at the top center. Indexing by column and row makes the sheets easy to use. For example, if the northwest sheet is 1-1 (column 1, row 1), then the next sheet south is 1-2 (column 1, row 2), and the sheet east is 2-1 (column 2, row 1). The index accompanies the completed survey when it is submitted for map assembly.

Field and Office Activities

Preliminary Research

The soil survey party leader should arrive in the area before soil mapping begins and generally before the other party members do. This allows the party leader time to become familiar with the area, review preliminary data, investigate the major soils and their pattern of occurrence, review the stated purposes of the survey, check the adequacy of the base map material, and prepare a preliminary mapping legend. During the general premapping appraisal of the survey area, the party leader also assembles the information needed to schedule survey operations.

A well-established principle of research is to assemble the existing information about a subject first. Time and effort are saved and costly errors are avoided if what is already known is used. The time required to find and appraise existing information is usually small relative to the time required to compensate for failure to use the information. Even for areas about which little is thought to be known, a diligent search usually uncovers useful information. In addition, information about adjacent areas can often be applied to the survey area.

If an older soil survey has been made, it is generally the most important reference available. Soil surveys made in the United States before 1920 emphasized the character of the parent material. The maps commonly provide some of the best information available for dividing the survey area into sections within which parent material is reasonably uniform. Many soil surveys made between 1920 and 1930 provide most of the information needed to broadly characterize the area and its soils. Those made between 1930 and 1940 provide a very important part of the information needed for identifying map units. The earlier surveys are also useful for identifying map units, but they must be used in conjunction with a systematic preliminary field study. It is helpful to examine mapping and examples of established soil series in nearby areas that have been recently surveyed.

Unpublished soil surveys of scattered farms are another source of information about the area. The value of this information depends on the quality of the legend and consistency of mapping over long periods. Regardless of the quality of the legend, the scattered farm mapping should not be made a part of the modern soil survey without careful field checking.

A soil survey is a study of the geography of soil. Maps detail geographic information. Aerial photographs, topographic maps, and other maps are useful references whether or not they are used as the mapping base. Each kind of map shows features that the others do not.

Topographic maps are the best references for appraising relief for most areas. Maps and texts on geology for many areas have been published by the U.S. Geological Survey and by comparable State agencies. The publications are on various subjects, such as bedrock geology, surficial deposits, and water or mineral resources. The maps were made at various scales and degrees of detail. Almost all contain important information about the parent material of soils and related factors. Although not as extensive as for geology, maps showing vegetation have been published for many areas. The U.S. Forest Service and State agencies are likely sources. In addition, climatic maps that are commonly at small scale and general in nature are available. The cartographic staff of the Soil Conservation Service, local libraries, and university libraries are good sources of information about what has been published and where it can be obtained.

Local sources—libraries of local schools, universities, municipals, historical societies, State agencies—are sources of published material on soils, agriculture, geology, geomorphology, hydrology, climate, engineering, biology, history, and related subjects. If a university is located within reasonable distance of a survey area, graduate theses may provide significant material. Local weather stations can provide data on temperature, precipitation, and other weather events. Reports of the Bureau of the Census and of USDA's Economic Research Service and National Agricultural Statistics Service are authoritative references on land use and crop production. A computerized bibliographic search service can also provide references for publications about the survey area.

Faculty members of universities often have information that is not available in published form or know of published information that the party leader has not found. The local representatives of the Cooperative Extension System, area and district conservationists of SCS, and vocational agriculture teachers may also be sources of knowledge that is not generally available. Representatives of planning boards, sanitation departments, highway departments, and the like are knowledgeable about matters that are important for interpreting soils and designing map units. Strong working relationships with the office of the State geologist and with geologists working in the survey area are very important. They can provide much information that is helpful in understanding soil-rock relationships.

Some information not directly related to soils is also helpful in planning, organizing, and conducting a soil survey. Questions that should be answered include:

1. What is the present land-use pattern? Is it relatively uniform or a mixture of conflicting uses and intensities? Are there political or economic problems associated with present land uses?
2. Is there a land-use policy or plan for the area? Is it active and effective? What changes in land use does it outline?

3. What is the general ownership pattern? Is it expected to change?
4. Are mineral rights important in the area? Who owns them?
5. Are water rights, either ground or surface, controlled? Does water supply limit land use and continued growth and development? What is the quality of the water?
6. What cultural, social, or economic factors influence or control land use?
7. What qualities of the area (climate, soils, mineral, and so forth) are unique, valuable, or limiting for some uses?

Not all of these questions are universally important, nor is the list complete. The answer to these questions, however, can be important in satisfying the needs for the soil survey.

Promising sources of reference material have been mentioned. The amount and significance of existing information varies widely, but in most parts of the United States it is substantial. Preliminary research can provide much, if not most, of the information about the soils of the area and their geography that is needed to start field studies and prepare a preliminary mapping legend. Preliminary research provides the basic data for interpreting the soils.

Preparing the Mapping Legend

Preparing the mapping legend is the principal duty of the party leader after preliminary field studies have been completed. The purposes of the survey having been stated in the memorandum of understanding, the party leader consults with other specialists and determines what soil areas are significant. Soils and map units that can be consistently identified and mapped are then described, and names and symbols are proposed for them.

The mapping legend is composed of two parts: (1) the descriptive legend, which contains descriptions and classification of the soils, the identification legend, the legend of conventional and special symbols, and the general soil map and (2) mapping aids such as a genetic key, table of soil characteristics, and notes about individual soils or map units. The mapping legend contains the primary references and the principal guides for each survey party member. It is designed to serve the purposes of the soil survey and is unique to each area.

Preliminary studies are made in a survey area to identify sets of soil properties that are repeated in characteristic landscapes and are mappable. Not all of the soil map units needed for the complete survey can be anticipated at the start. An initial mapping legend is prepared after preliminary investigations and test mapping. The initial mapping legend should include only the descriptive legend and mapping aids for those soils, map units, and other features that have been definitely identified as needed. The number of map units in the initial legend depends on the scope of the initial studies, complexity of the area, and intensity of the survey. Map units must be defined and described carefully. These descriptions are the guidelines for mapping soils and the standards against which possible additional map units are evaluated as the survey progresses. The mapping legend should be made available to each member of the party before mapping begins. It is revised as needed during the soil survey.

As the survey progresses, other material is added to the mapping legend. This makes a soil handbook for the survey area. The soil handbook contains all of the information and other related facts about the genesis, morphology, classification, and interpretation of the soils of the survey area. By the time mapping is completed, the soil handbook should contain all of the material needed for the published soil survey.

Field Operations

Soil mapping is a technical art. It requires sound training in soil science and familiarity with the principles of the earth sciences. A skilled soil scientist is a perceptive observer and understands the significance of landscape. Subtle differences in slope gradient or configuration, in landform, and in vegetation can be important indicators of soil boundaries. The soil scientist must learn to associate sets of landscape features with sets of internal soil properties to be able to visualize the pattern of the soils. A skilled mapper is able to abstract the essentials of the soil pattern and sketch this pattern on a map.

Above all, a good soil scientist strives for accuracy and is truthful about the reliability of the maps. The demanding standards for soil mapping must be maintained throughout such a survey regardless of vegetative cover.

Even though the map scale is adequate and the legend is well designed, the legibility and usefulness of the maps depends on the skill and judgement used in applying the legend. Some soil boundaries are more important than others and require greater accuracy. Time and effort must be spent to delineate small areas of soil that contrast with neighboring soils. In mapping consociations, for example, boundaries between highly contrasting soils, such as a wet soil and a dry soil or a clayey soil and a sandy soil, must be located as correctly as possible.

The greatest time and effort is spent delineating dissimilar soils that are more limiting for use than nearby soils. Small areas of some soils are deliberately mapped with their more extensive neighbors if the two kinds perform similarly for the purpose of the survey. Useless detail is avoided. Special symbols are used to indicate significant areas too small to be delineated. The skill and judgment of the mapper are part of the art of separating the landscape into meaningful units of soil and then recording the units on a map.

Using Aerial Photographs.—Aerial photographs provide important clues about kinds of soil from the shape and color of the surface and the vegetation. The relationships between patterns of soil and patterns of images on photographs can be learned for an area. These relationships can be used to predict the location of soil boundaries and kinds of soil within them.

Light and dark tone on panchromatic photographs and color differences on color photographs, for example, are records of light reflected when the photographs were taken. These records must be interpreted by relating the visual pattern on the photographs to soil characteristics found by inspection on the ground. Using the aerial photographs of an area, a soil scientist learns many relationships between the photographic images and soil and landscape features, but many uncertainties inevitably remain. Awareness of the factors that affect an image is required to interpret the aerial photographs as fully as possible.

The techniques used to predict specific kinds of surface features, landforms, attributes of soils, and soil boundaries from photographs are continually being refined. Published material provides information about the techniques and the kinds of clues used by photo interpreters. Some publications provide helpful illustrations of specific features. Nevertheless, reliable predictions of many features in a particular area require experience in relating the images on the photographs to what is actually on the ground.

Such features, as roads, railroads, buildings, lakes, rivers, field boundaries, and many kinds of vegetation can be recognized on aerial photographs.

Relief can be perceived by stereoscopic study. Shadows and differences in tone between slopes that faced the sun and those that did not at the time of photography also help show relief. Relief features help locate many soil boundaries on the map. Relief also identifies many kinds of landforms which are commonly related to kinds of soil.

Many landforms—terraces, flood plains, sand dunes, kames, eskers—can be identified and delineated reliably from their shapes, relative heights, and slopes. Their relationship to streams and other landforms provide additional clues. The soil scientist must understand geomorphology to take full advantage of photographic imagery.

Some landforms are less easily identified, but most images contain clues that narrow the choices of the kinds of landforms represented. Experience in interpreting tone patterns, configuration of relief, and patterns of drainageways commonly permits correlation of these patterns with kinds of geologic deposits and geomorphic features in an area. As the survey progresses, experience generally increases the reliability of predictions.

Differences in tone or color may reflect soil differences. Differences caused by man-imposed land use usually can be recognized by the angular shapes and abrupt boundaries of the areas. Other tonal differences may reflect differences in vegetation that relate to soil or differences in the surface of bare soil. Certain patterns of tone or color may reflect local soil patterns within areas that can be mapped in one day. Different soil associations have distinctive patterns that can be recognized on photographs. These patterns serve as bases for drawing tentative soil boundaries and for predicting kinds of soils. These predictions of soils and boundaries must be verified in the field.

Accurate soil maps cannot be produced solely by interpretation of aerial photographs. Time and place influence the clues on the photographs. Shades of gray commonly reflect the state of the soil moisture when the photograph was taken; but the soil moisture changes with time. Clues to soil boundaries that are evident on photographs taken at one time are not necessarily evident at another time. The activities of man have changed patterns of vegetation and confounded their relationships to soil patterns. The clues must be correlated with soil attributes for each set of photographs, and predictions of soil properties from such clues must be verified in the field. The accuracy of maps improves as fieldwork and experience increase.

Stereoscopic examination.—Before an area is surveyed, making a careful stereoscopic study is helpful (fig. 4-1 (no longer available)). The area is scanned with a stereoscope for a general impression of farming, relief, geology, landforms, kinds of soils to be expected, soil moisture states, and so forth. Important features that can be accurately identified are sketched lightly on the photograph. Some features can be determined with more certainty than others. Images that help identify obscure features can be marked. The following steps are commonly used in preliminary studies.

1. Drainageways, streams, and ponds are tentatively sketched.
2. Roads, buildings, and other location references are identified.
3. If soils have been mapped along the match line with an adjacent photograph, the soil boundaries are transferred to the outside edge of the match line. Some soil boundaries can be tentatively extended onto the unmapped sheet.
4. Additional features can be lightly penciled if they can be identified with confidence: boundaries of flood plains and stream terraces, boundaries of wet areas and water, prominent landforms such as escarpments and areas of rock outcrop, gravel and borrow pits, ridge lines, sinkholes and wet spots.

Routes of traverse can be placed during these preliminary studies. Obstacles can be identified and plans made to avoid them. Enough field checking is planned to ensure maximum accuracy with a minimum of walking per unit of area mapped.

As experience is gained in an area, many soil boundaries and kinds of soil can be tentatively predicted on the photographs. These predictions must be verified in the field, but preliminary interpretation can increase the quality of mapping. During such preliminary studies, a map should not be cluttered with conjectures. Only features that can be predicted with confidence are marked.

After fieldwork, mapped sheets are examined again while the landscapes are fresh in the mind and can be related to the stereoscopic images. If considerable time elapses, details may be forgotten. Questions that the examination may raise become more difficult to resolve, and a special trip to the field may be needed. Because dense vegetation or other conditions may obscure the image on a photograph, some drainageways, slope breaks, and soil boundaries that are observed in the field may be impossible to place accurately on a photograph. These features can be sketched tentatively in the field, and their locations later checked by stereoscopic study for necessary revision. Thorough stereoscopic study of areas that have been mapped commonly reveals places where soil boundaries or stream symbols need to be refined to conform to relief. The traces of roads in heavily forested areas may be obscure on single photographs but evident under the stereoscope. If some boundaries inadvertently were not closed during field mapping, they can often be closed with confidence on the basis of stereoscopic study.

In the field, roads, houses, streams, field boundaries, individual trees or bushes, and the like are used to identify locations on the ground with points on the base map. The photograph can be oriented so that the relative position of its images corresponds to the relative position of ground features from the vantage point of the surveyor. The photographic images of surface features that mark soil boundaries can be followed in the sketches of the boundaries. Boundaries that are not evident on the photograph can be sketched in relation to identifiable ground features.

In some areas a stereoscope used in the field with stereoscopic pairs of photographs is helpful. A pocket stereoscope can be used on the hood of a vehicle or on a dropleaf shelf (fig. 4-2 (no longer available)). It can be carried while walking. The stereoscope and pairs of photographs can be used to relate the landscape features to the stereoscopic images. Kinds of soils and the location of boundaries can be predicted from the stereoscopic image. Boring or digging is needed to identify soils positively and to verify predictions, but stereoscopic study commonly reduces the number of borings that are needed to locate the boundaries of an area.

Plotting soil boundaries.—A soil scientist plans the day's work as a series of trips across the area to be mapped. Proceeding along these routes, the soil scientist predicts soil areas, the kinds of soil in the areas, and the boundaries that separate different kinds of soil. These predictions are checked as the areas are crossed. Finally, boundaries and kinds of soils are plotted on the map. Thus, fieldwork consists of a sequence of predictions and verifications.

To the extent feasible, mapping is scheduled to proceed systematically across contiguous areas. When mapping is resumed each day, the mapping of the previous day provides points of reference. The boundaries that were projected tentatively the day before are predictions to be verified. The soil patterns and the clues for interpreting the landscape are already understood. Mapping systematically across contiguous areas contributes greatly to both efficiency and quality of the work.

Ground traverses are planned to cross as many soil areas as possible. Soil areas generally conform to the orientation of relief, which is commonly related to drainage courses.

Consequently, most soil areas and most soil boundaries can be crossed by traveling at an angle to the secondary or tertiary drainage courses. The traverses are spaced so that the boundaries that are identified and projected on one traverse can be identified and continued on the next. Traverse spacing depends on the complexity of the soil pattern, visibility, and amount of detail required by the survey objectives. In fairly detailed surveys, for example, traverses are planned to pass within 200 to 400 meters of every point in the area, thereby permitting detection of small areas of contrasting soils.

Where aerial photographs are used as the mapping base, a predetermined line of traverse need not be followed consistently if there are sufficient reference points for accurate location. A traverse can deviate from a planned route to cross landscape features that may be marks of soil boundaries. Wandering from place to place at random, however, should be avoided. Aerial photographs assist in avoiding obstacles on the route. If boundaries are observed to run in a different direction than had been anticipated, the plan can be adjusted.

From any point of observation, the soil scientist looks along the projected route and predicts the kinds of soils on the landscape ahead. A break in slope gradient, a change from convex to concave slope configuration, a change in the color of the surface of a plowed field, the margin of a swamp or forest, the edge of a stony area, a change in kind or vigor of crops—these observable features can be related to soil boundaries. If possible, these features are identified on the aerial photograph. Some may already have been marked during the stereoscopic examination. If soil boundaries follow identifiable features, they are lightly traced on the photograph in pencil. Boundaries that are not evident on the photograph are sketched on the map in relation to identifiable features. Most features must be located and sketched by estimating location in relation to the point of observation and other known points. Tentative soil boundaries are sketched for perhaps 100 to 200 meters ahead and on either side of the point of observation. Natural and cultural features that are immediately ahead, such as a stream or drainageway, are also sketched on the aerial photograph.

Some soil boundaries are sharply defined (fig. 4-3). Others are plotted as lines midway in zones of gradual transition from one soil to another (fig. 4-4). A judgment is made about whether a broad transition zone is a discrete mappable soil unit or should be split and its parts included with the soils on either side. Every part of the mapped area must be enclosed in a boundary and assigned a symbol.

After predictions are made about the soil areas and boundaries are sketched on the map, the soil scientist walks across the predicted boundaries. The course is adjusted as necessary to investigate the transitional zone and any unusual features. Slope gradient is estimated or measured with an Abney level or a clinometer. As a predicted soil boundary is approached, especially in a broad transitional zone, the soil is examined to locate the significant changes in soil properties.

As a projected delineation is crossed, the distribution of microdepressions, microknolls, tiny areas of different vegetation, convexities and concavities, and other features too small to delineate are observed. The soil is examined at a place where the microfeatures suggest that the predicted dominant soil should be best expressed; and this portion of the delineation is identified positively. The prediction may be confirmed, or a different kind of soil may be found. Where microfeatures suggest important inclusions, additional observations are made to ensure that the evaluation of the whole delineation is good. Sites for examination are not chosen at random if reasons exist for dividing the projected delineation into parts that are the predicted soils and parts that are not.

FIGURE 4-3

Sharply defined boundary between sand soils on a high terrace (at right) and loamy soils on a lower terrace.

FIGURE 4-4

Broad transition zones between contrasting soils. Dark areas are Brookston soils; light areas are Crosby soils.

The number of places at which observations are made depends on the certainty of the predictions and the objectives of the survey. If predictions about the kind of landscape under examination have been valid many times before, soils need be examined in only a few places. If the landscape features have not been consistently related to kinds of soils, many places must be examined. The depth of the examinations depends on the depth of differentiating criteria for the map unit and on the confidence in the predictions about the kind and uniformity of soil material at a given depth. The examination itself is rapid and is mostly a search for a few properties that identify the soil. A small sample of a pedon is observed; seldom is an entire pedon studied.

After a delineation has been identified and crossed, the soil scientist turns and looks back on the landscape from a new vantage point. A final judgement is made on the boundaries and symbols. If mapping is done on an aerial photograph, the photographic images are checked against the landscape features before the final boundaries are sketched.

Soil boundaries are projected on either side of the traverse as far as they can be seen and identified with reasonable certainty. The ends of their projections are checked from the next traverse. Many boundaries can be seen throughout their lengths. Other boundaries can be predicted on the aerial photographs with a high degree of certainty. In forests, for example, visibility may be a few tens of meters or less; but, where a slope break that marks a soil boundary can be seen under the stereoscope, the boundary can be plotted much more accurately by a study of the photographs than by an observation on the ground. A soil boundary that is found at one point to correspond to a change in color on the photograph is commonly continued along the change on the photograph even though the boundary itself is not visible on the ground during mapping. In detailed soil mapping many boundaries between traverses are drawn on the basis of variations in the photographic image.

In mapping, a pattern of soils and landscapes is conceived, rather than a group of individual map units. Certain soils are typically found together. The number of soils in any locality is usually small.

In most places landscape features mark the kinds of soils. But landscape features do not identify soils everywhere, and by no means can all internal soil properties that are used to define map units be correlated with external features. Where soil boundaries cannot be predicted with confidence, they may be identified by direct examination of the soil.

In some areas, important attributes of the subsoil or substratum are not related to surface features. Depth to bedrock, layers of contrasting texture, salt in the substratum, and similar attributes may have no visible relationship to the vegetation or other natural features but may be important when the soil is used. When desert is irrigated, when wet soils are drained, or when highways are built, soil differences that are not reflected in landscape variations may become important.

Conditions of this kind occur in most survey areas. If common mapping techniques are used, the predictions frequently turn out to be inaccurate for some areas. Unless the mapper can reappraise the landscape and reliably predict the extent of the soil, the boundaries must be determined by actual examination.

In large areas where landscape has low predictive value, geologic history and geomorphology may provide guides to stratigraphy, depth, and distribution of the kinds of rocks that are related to specific soils. The general hydrology of an area may indicate where salt-charged water has moved and where the salt has concentrated. Streams and their traces help in locating areas that have layers that differ in texture. As much preliminary information as possible is assembled to help determine the pattern and scale of soil variability. This information helps in planning the route and spacing of traverses and the spacing of samples within the traverses.

In survey areas that are to be irrigated, samples of critical layers may be taken for special field-testing or examination to determine boundaries. These samples may be taken at points on a predetermined grid or at predetermined points along lines of a traverse.

Where internal properties of soils are used for locating boundaries, a predetermined line of traverse is generally followed. Side trips are made wherever landscape features or experience with the soil pattern indicates that there is probably a significant soil change between traverses. Generally, the soil is examined at some standard interval along the traverse to locate important differences. If properties deep in the soil are important, the plan may require observations at fixed depth-intervals to a certain depth, such as 1 meter, and with layer depth intervals to greater depth.

In most areas, some feature of the landscape or some aspect of the pattern of soils already mapped on an adjacent traverse provides a basis for predicting the location of soil boundaries. As evidence of change is observed, preliminary observations are made. Where the evidence indicates an important soil boundary, the soil is examined in more detail or to a greater depth to verify the prediction.

Where power equipment can be moved freely across the countryside, it can be used to examine the soil to considerable depth at close spacing. Map units that are based on soil properties deep below the surface can be delineated with increased accuracy and the rate of progress can be greater if the geographic distribution of these properties is consistent with the scale of mapping.

Neither standard intervals between traverses nor intervals for investigating the soil within traverses can be specified with certainty. The plan is adjusted to the direction and scale of the soil boundaries and the variability of the important properties. This kind of evidence is commonly obtained as the survey progresses, and the mapping plan can be altered to fit the accumulated evidence.

A great deal of skill and judgement is required in areas of low predictability. Rarely are the soils at two sample sites exactly alike. Study of a single site is not enough to identify a significant area. Map units are defined to include the variability within areas large enough to be meaningful for the objectives of theurve2(i)-2(6(i)- 6(o)Tlb r)3(e)t(U6(c)4(9 o)2(f)5(a p)2(a)6(n))6(s)1(1(i

In areas of low accessibility, roads or trails may be traveled; but the mapper must understand that roads and trails commonly follow the easiest routes and avoid the steepest slopes, the wettest areas, and the other places that are difficult to cross. Such places are integral parts of soil associations and should be observed by the mapper on the ground.

Transects are commonly used to determine the composition of map units. In transecting, a planned line of travel is followed as closely as possible and the soils are observed at predetermined regular intervals.

In transecting, routes of travel are systematically planned to give a valid sample of the area. Taxa phases and other features are identified and recorded. Distances or number of points along the route identified by each taxon provides estimates of the composition of the map units. In surveys without easily predictable patterns, soils are sampled most efficiently if the transect lines are selected at random. Lines oriented to cross the drainage pattern often provide the most information about the pattern of soils.

Sample blocks, instead of transects, are used in some surveys to determine the composition of map units. Blocks do not replace transects, however, they permit one to observe spatial patterns not always evident from transects. Sampling by transects is usually more efficient than block sampling for estimating map unit composition.

Methods for sampling by blocks vary among soil surveys. One method imposes a grid of appropriate divisions on the entire area. Grid segments are numbered, and sample blocks are selected by drawing numbers at random. Each sample block is remapped in greater detail, and the area of each kind of soil is measured. These data provide estimates of the kinds and proportions of soils in each map unit. The number of blocks and their sizes are determined by statistical principles with consideration of mapping scale, the limits of confidence required for the survey, the general pattern of soils, and the relative size of soil areas.

Mapping of organic soils follows the same general principles as mapping of mineral soils. Organic soils, however, have some special relationships to landscape and vegetation. These relationships affect mapping of organic soils at all levels.

In preparing the mapping legend, systematic investigation of organic soils is required as for other kinds of soils. A thorough knowledge of the genesis of organic soils is required, as well as high-quality imagery and appropriate tools.

The kind of organic soil in many areas is closely related to the kind and pattern of native vegetation. Since many areas of organic soils are comparatively undisturbed, reliable relationships between soils and plant communities can be established. Thus, high-quality imagery from aerial photography and other forms of remote sensing can be very useful in preparing legends and in mapping these soils.

Where organic soils have formed directly on a mineral substratum, the environment may be rather uniform over extensive areas. Although the kind of organic material can vary with depth because of changes in climate over the period in which the soils have formed and because of differences in rate of decomposition that result from the accumulation of the organic material, such variations commonly are uniform over large areas. The properties of a large area of organic soils, therefore, can be accurately estimated from the properties of a small sample.

Organic soils are not uniform in some areas that have microrelief of hummocks and swales. The hummocks commonly contain fibric material, and the swales contain hemic and sapric material. In such landscapes, many more sites must be examined to determine the nature of the soils.

These relationships and processes generally apply where organic soils are formed by lake filling. Each basin in which organic soils have formed has a unique local environment, and the organic soils in adjacent basins may differ considerably. This is particularly true in irregular glacial moraines. For example, limnic materials may be covered by only a thin mantle of organic material in some basins and by several meters of organic material in others.

Areal relationship must be kept in mind when estimating the extent of the different soil components within basins, particularly small basins. For example, one kind of organic soil occupying a rather narrow fringe of a bog may cover a greater area than the organic soil in the center.

In northern glaciated areas in particular, organic soils may form around the edges of swamps that have open water in the center while adjacent swamps lack surface water.

In some areas, a layer of water can underlie the organic soils at a relatively shallow depth. Such areas may not support much weight and should be investigated with caution.

Organic soils of some coastal wetlands lack distinctive landscape features and, additionally, are poorly accessible. In these areas, the soil scientist relies on other features to predict kinds of soils. Patterns and kinds of soils in many coastal areas can be related to the position of such natural features as shores, deltas, streams, and adjoining higher lands. The soil scientist must have a thorough knowledge of the geomorphic history of the area in order to make reasonable predictions related to such features and to determine the places where transects and other field checks will best verify the predictions.

Completing Field Sheets

Most soil survey field sheets are individual photographs or compiled photobase maps. As each field sheet is completed it is joined with adjacent sheets and checked for errors.

Joining field sheets.—Each pair of adjacent field sheets shares a common match line. During mapping, soil boundaries are commonly extended beyond the match line to be transferred to the adjacent sheet; but when the field sheet is completed, soil boundaries and other features may be discontinued at the match line. The mapping on each field sheet should be carefully matched with that on adjacent sheets to check boundaries and delineations. Roads and streams also should be continuous from one sheet to another. Special care is needed at the corners where four field sheets join.

If soil boundaries are sketched on overlays, field sheets are matched before soil lines are transferred to the soils overlay. Matching should be completed while the photographic background is available.

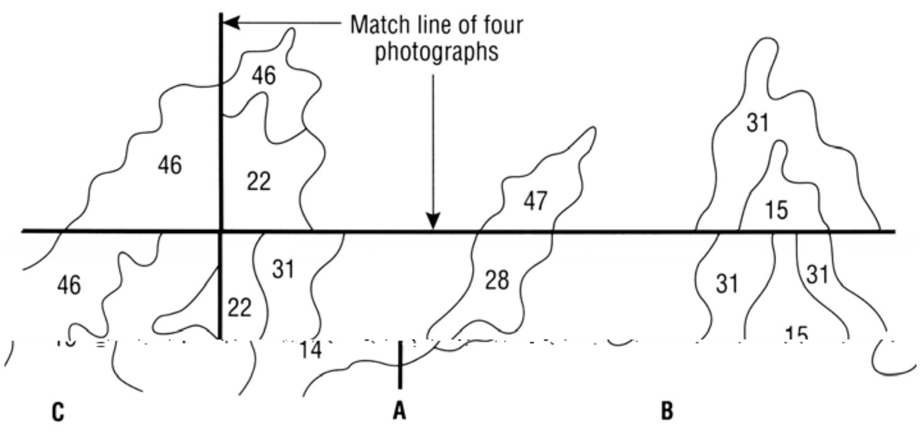
The mapping on one field sheet can be matched with that on an adjacent sheet in several ways. For aerial photographs, the mapped field sheet and an adjoining unmapped field sheet can be placed under the stereoscope and the images meshed. The soil boundaries and other features on both sides of the match line can then be transferred from the completed field sheet to the unmapped sheet.

Another method, that is particularly useful if adjoining sheets vary in scale, is to transfer boundaries by reference to the photographic images. The relationship of the soil boundaries to images of isolated trees, clumps of bushes, field corners, and the like are observed along the match-line. Images of the same features are located along the match line of the adjoining photograph, and the boundaries are transferred or checked in relation to the images.

When the second field sheet is mapped, boundaries of delineations that cross the match-line may be altered. Consequently, the boundaries at the match-line must be rechecked after both field sheets have been completed. If different individuals map adjacent field sheets independently and the completed sheets are joined, a match indicates the uniformity of fieldwork.

If there is no systematic method of joining sheets, errors are easily made that may require additional fieldwork before the final map can be compiled. Figure 4-5 illustrates some errors on unmatched field sheets.

FIGURE 4-5



Failure to join adjacent field sheets: *A,* boundaries do not match where four field sheets join; *B*, boundaries match but symbols do not; *C*, symbols match but boundaries do not.

Inking field sheets.—After mapping has been completed on each field sheet, it may be inked to provide a permanent record and to provide a map from which copies can be made (fig. 4-6). All soil boundaries and symbols and important drainage features should be inked. Cultural features needed on the soil maps are determined before mapping starts and are specified in the legend.

Inks or leads that are reproducible photographically and are readable by automatic scanning equipment are preferred. The ink or lead used should be compatible with the base material, and the lines should be opaque. Several kinds of inks and leads are suitable. Commonly, pens that store carbon-base ink in a reservoir are used.

Several pens that make uniform lines of different thickness are needed for inking different features and for lettering. Line widths recommended for different features are indicated in the list of conventional symbols on fig. 4-7.

Different groups of features generally are inked in separate operations. Drainage is inked first and inspected to see that individual streams are properly joined, matched, and classified. Then, culture is inked. The classification of roads and other features is checked at the same time.

FIGURE 4-6

Example of a field sheet.

Soil boundaries and symbols are inked next. Finally, the place names are lettered. In some surveys, however, certain features may not be inked. For example, if the photographic image of all roads is pronounced, they do not need to be inked.

If photobase map sheets are used as field sheets, the inking can be done on transparent overlays. As many as three overlays can be used: one for culture and drainage, one for soil boundaries, and one for symbols. Together these form a composite overlay and can be used in printing the final map. The individual overlays can be used in printing special purpose maps. Adhesive-backed, clear stripping film with printed symbols can be applied to the overlay to save handwork.

In inking soil boundaries, a good procedure is to close each boundary within one section of the field sheet. When the boundary of a small area is closed, its symbol is placed as near the center of the area as practical. More than one symbol is placed in areas that extend for long distances and in those that have intricate shapes.

Mapping along the match lines may be left in pencil until the field sheets have been joined.

Soil symbols on all sheets should be positioned to be read horizontally, or as nearly so as possible, when the map is oriented in one direction. Usually, north is toward the top of the map. If an area is too small to contain a symbol, the symbol may be placed outside it and a leader used to indicate the area to which the symbol applies. The leader should be so placed that it cannot be confused with a soil boundary.

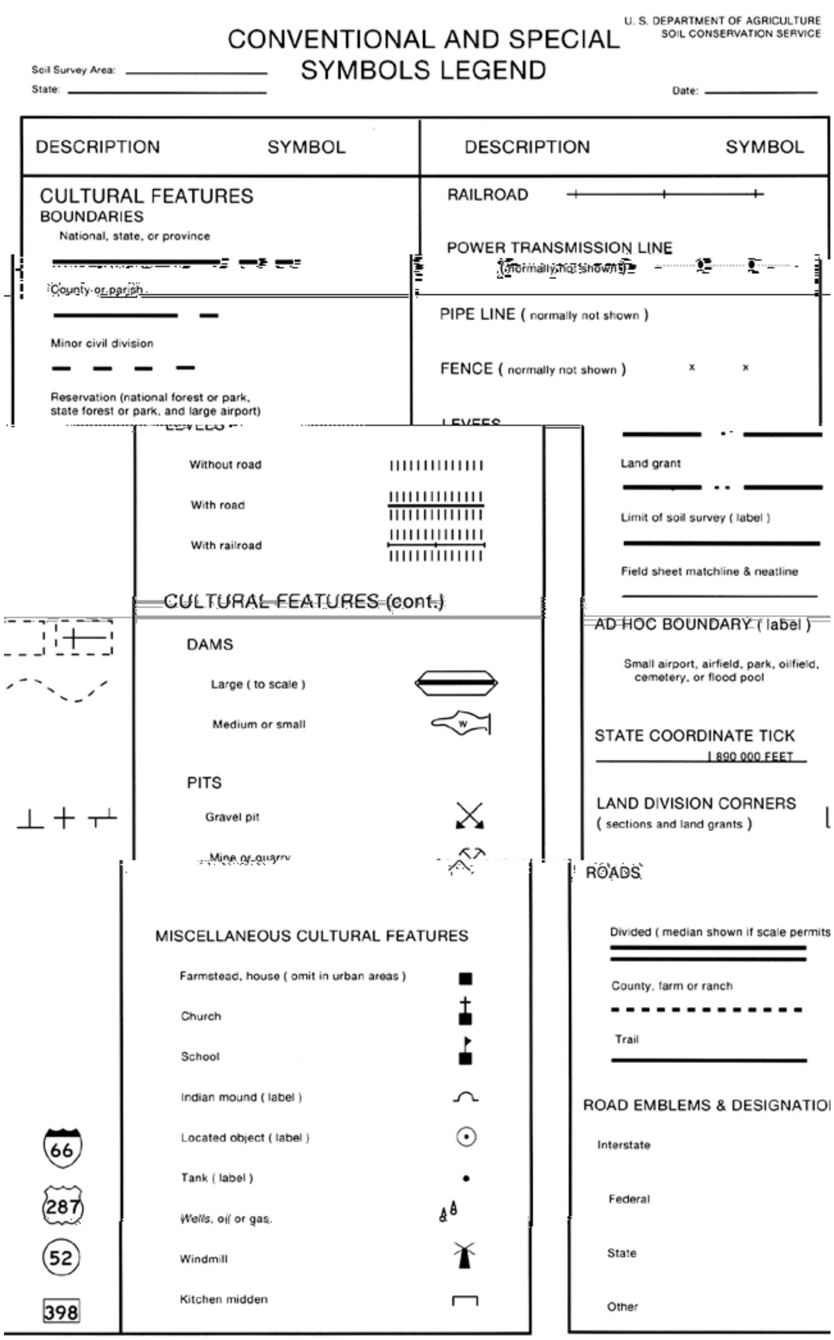
Place names should be inked last so that they may be placed where they will not obscure soil symbols and other details. Place names should be arranged so that they clearly identify their features. Names of features expressed as lines on the map are oriented parallel to the lines. Names of other features are usually oriented horizontally, with north at the top. Important features that serve as landmarks should be named on each sheet. Names of streams should be so positioned that no confusion arises about which branch is meant. Incorrect and correct placement of names are illustrated in figure 4-8.

FIGURE 4-7

Rules of Application for the Use of Conventional
and Special Map Symbols for Soil Surveys

[redacted]

FIGURE 4-7 (continued)



U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

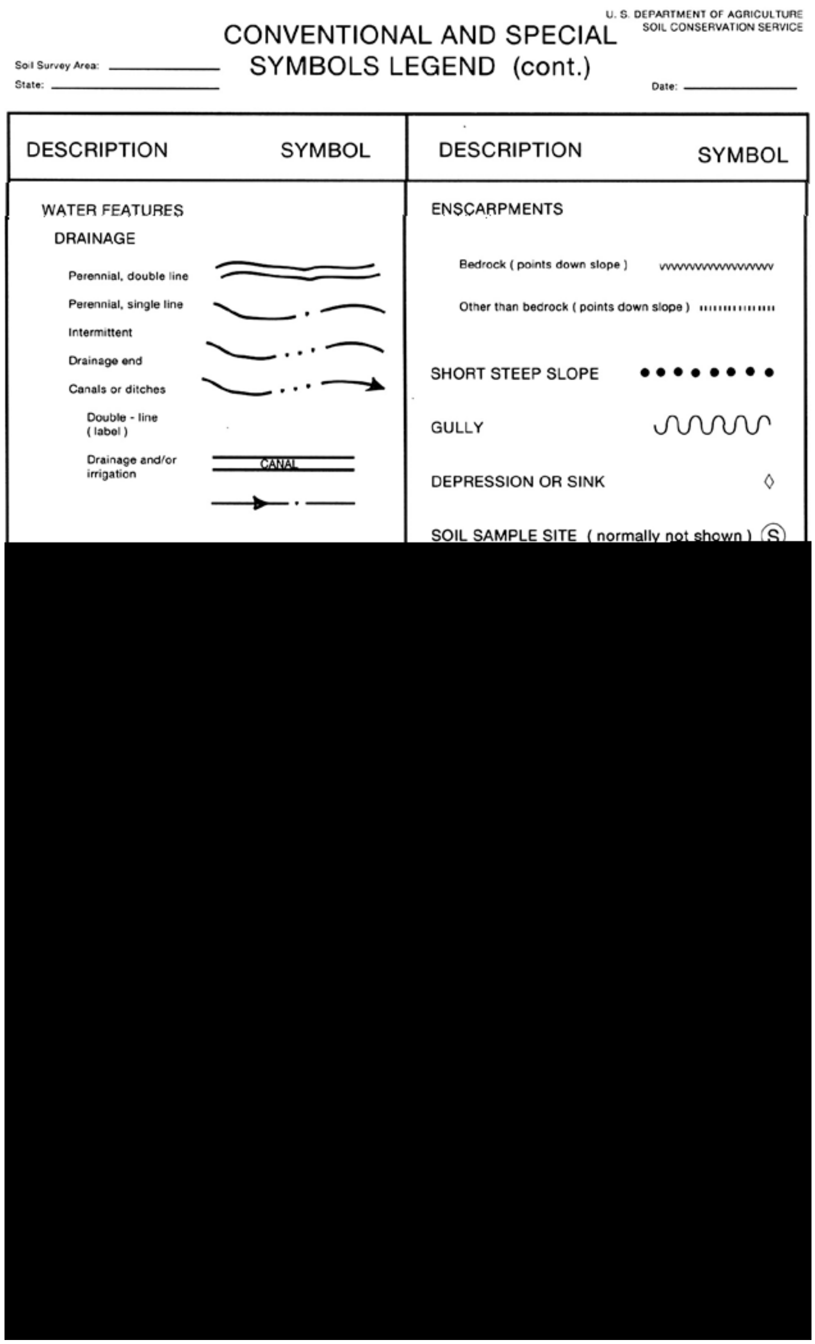
CONVENTIONAL AND SPECIAL SYMBOLS LEGEND

Soil Survey Area: ______
State: ______
Date: ______

DESCRIPTION	SYMBOL	DESCRIPTION	SYMBOL
CULTURAL FEATURES		RAILROAD	
BOUNDARIES		POWER TRANSMISSION LINE (normally not shown)	
National, state, or province		PIPE LINE (normally not shown)	
County or parish		FENCE (normally not shown)	x x
Minor civil division		LEVEES	
Reservation (national forest or park, state forest or park, and large airport)		Without road	
Land grant		With road	
Limit of soil survey (label)		With railroad	
Field sheet matchline & neatline			

DESCRIPTION	SYMBOL	DESCRIPTION	SYMBOL
AD HOC BOUNDARY (label)		CULTURAL FEATURES (cont.)	
Small airport, airfield, park, oilfield, cemetery, or flood pool		DAMS	
STATE COORDINATE TICK	1 890 000 FEET	Large (to scale)	
LAND DIVISION CORNERS (sections and land grants)		Medium or small	W
ROADS		PITS	
Divided (median shown if scale permits		Gravel pit	
County, farm or ranch		Mine or quarry	
Trail		MISCELLANEOUS CULTURAL FEATURES	
ROAD EMBLEMS & DESIGNATIOI		Farmstead, house (omit in urban areas)	
Interstate	66	Church	
Federal	287	School	
State	52	Indian mound (label)	
Other	398	Located object (label)	
		Tank (label)	
		Wells, oil or gas.	
		Windmill	
		Kitchen midden	

FIGURE 4-7 (continued)


U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CONVENTIONAL AND SPECIAL
SYMBOLS LEGEND (cont.)

Soil Survey Area: ____________
State: ____________
Date: ____________

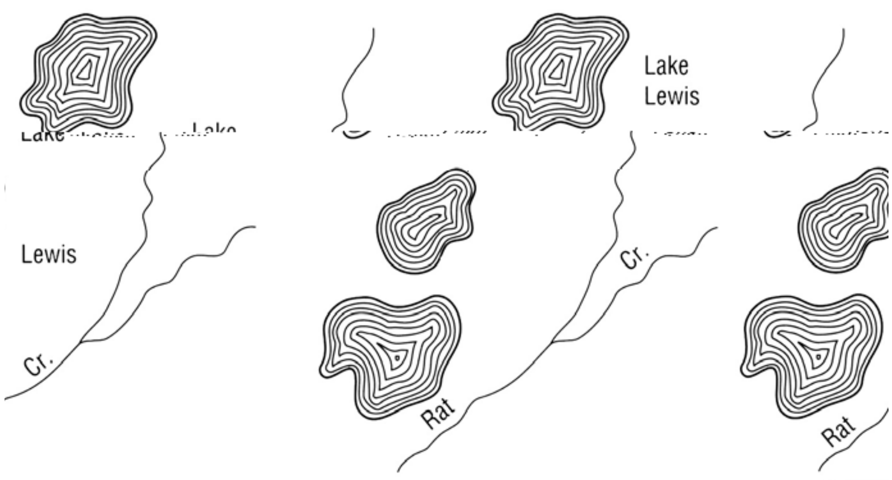
DESCRIPTION	SYMBOL	DESCRIPTION	SYMBOL
WATER FEATURES		ENSCARPMENTS	
DRAINAGE		Bedrock (points down slope)	
Perennial, double line		Other than bedrock (points down slope)	
Perennial, single line		SHORT STEEP SLOPE	
Intermittent		GULLY	
Drainage end		DEPRESSION OR SINK	
Canals or ditches		SOIL SAMPLE SITE (normally not shown)	
Double - line (label)	CANAL		
Drainage and/or irrigation			

[redacted]

Neatness and legibility are important in lettering. Maps with many soil symbols, boundaries, cultural features, and the like become confusing unless the lettering is done with special attention to high standards. Every soil scientist should learn the art of freehand lettering.

A simple style of lettering should be used. Freehand styles that use single strokes are best for inking field sheets. The pen is held as in writing and the strokes are made with an even steady motion. Slant or vertical lines are made with a downward stroke: horizontal lines are made with a stroke from left to right. The slant of the letters is kept uniform.

FIGURE 4-8



Location of place names. Only the uppermost of the three lakes is Lake Lewis, and Rat Creek is the lower of the two branches.

Checking field sheets.—Each field sheet should be checked for open boundaries, areas without symbols, and other errors. Fieldworkers usually check their own sheets, and another person may check each sheet for completeness and legibility. The party leader should be responsible for checking the mapping of each party member. The mapping of beginners generally needs much checking. If different soil scientists map adjacent field sheets, the party leader can compare their mapping in the areas where the sheets join. During field reviews, supervisory soil scientists responsible for technical standards often check boundaries and symbols on samples of the field sheets of each soil scientist.

After mapping has been completed, the party leader should check all of the field sheets to see if any corrections and remapping are required. Omissions and inconsistencies increase the cost of map construction and delay publication. In order of frequency, the most common mistakes are:

1. incorrect joining at the match-line,
2. failure to close map unit boundaries,
3. omission of symbols or use of symbols not identified in the legend,
4. incorrect interpretation of cultural and drainage features, and
5. use of incorrect place names.

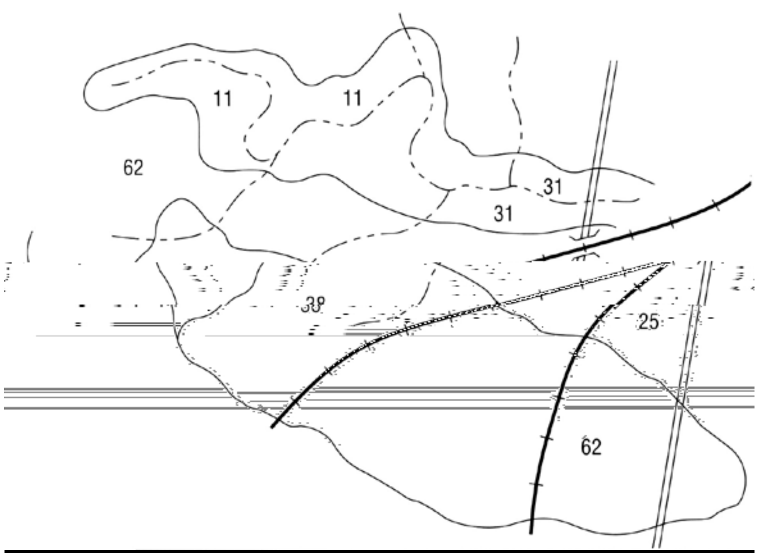
Failure to close soil boundaries is a common error. Figure 4-9 has three open boundaries—between map units 11 and 31, between units 62 and 25, and between units 38 and 62. The person who inked this sheet probably overlooked the lack of closure because of the drainage lines and railroad symbols that cross the area. Whatever the cause, the user cannot tell where one unit ends and the other begins. Someone may have to make a special trip to the field to close these boundaries.

Each area of a mapping unit must be separated from all adjoining areas by a soil boundary or the boundary of a body of water. Neither the single lines representing streams nor the conventional symbols for roads, railroads, and the like can serve as map-unit boundaries. Each area also must contain the symbol for only one kind of map unit.

Errors in symbols take various forms. A delineation on a field sheet might be closed without a symbol in it, or a symbol not listed in the legend might be used. Symbols might be illegibly drawn on the field sheet. Practice and care in lettering, good judgement in placing symbols, and care in erasing and reinking mistakes ensure legibility.

Various methods are available for checking field sheets. A good method is to color each delineation by hand on photographic copies of the filed sheets. A color check reviews each delineation and inspects boundaries throughout their length. In another method, each field sheet is divided into sections of perhaps 50 to 100 square centimeters. The delineations within each

FIGURE 4-9



The omission of a map unit boundary is a serious error, as in three places in this example.

section are checked one at a time, special care being taken at the edges of the section. If the map checkers are not familiar with the legend, they must be especially diligent in checking the symbols against the legend.

Incorrect placement of drainage or cultural features on the map can seriously reduce the accuracy of map unit boundaries. The location of streams, roads, and the like must be correct. Most errors in placement cannot be checked with precision except by stereoscopic study or field investigation. If accurate reference maps are available, locations of features on the field sheets are checked against them. If possible, locations are checked while mapping is in progress. Place names are verified with an authoritative source.

Keeping records of field sheets.—Each field sheet may be identified by a number that locates it on an index map of the area. The index map outlines and identifies all of the field sheets of the survey. Where single-lens aerial photographs are used, several hundred individual sheets are required and a systematic means of identifying their locations in the survey area is needed. Photographic indices are available for most areas where photographs are used. An index map can be made from a small-scale map by plotting the match-lines of the field sheets.

Each field sheet should contain the name of the survey area, the State, the date of the survey, and the names of the soil scientists who mapped that sheet. Names of others who inked or checked the sheet and its scale may be given also. Commonly, all this information can be put only on the back of the sheet. If it can be put on the front, it may be placed so that it will appear on photographic copies. A stamp can be used to provide spaces for the information.

The adjacent field sheets are identified on the margins of each sheet. When adjacent field sheets have been joined, the margins of the field sheets may be marked and initialed by the persons responsible. The joined match lines can also be marked on a transparent overlay over the map index.

Measuring the areas of map units.—Soil maps show both the location and the extent of map units. Measurements of the area of each map unit are needed. Planners, for example, need to know the extent of areas that have certain potentials or problems. Processors of farm products frequently need to locate areas that are suited to growing a certain crop. The data on an area are used to help decide whether certain map units of small extent are important enough to be retained on the published map. Measuring the areas also checks the map for open boundaries, delineations without symbols, and unidentified symbols. Measurements on field sheets are subject to errors caused by distortion of the photographs.

The area of map units can be measured for the entire survey area; or sample areas can be selected and the extent of map units in them measured and expanded to represent the entire area.

The accuracy of the estimate, based on sample areas, depends on the size of the sample and where the sample areas are located. If the sample is less than 5 percent of the total area, estimates are subject to relatively large errors. Generally, the sample should be at least 10 percent of the total area. Even with this large a sample, map units of small extent are likely to be either missed entirely or overestimated. The estimates of extensive map units by sampling methods are likely to be reasonably reliable. Estimates based on sample areas can be satisfactory for most uses of data for the major soils in the survey area.

If a sampling procedure is used, dividing the area surveyed into soil associations and sampling each association separately is helpful. The most accurate estimates can be derived from sample strips running all the way across each association and oriented at right angles to the prominent unit boundaries. The strips can be spaced to provide the needed sample size. Square areas and rectangular areas oriented at random yield less accurate estimates, especially if the sample is small.

Several methods can be used for measuring the area of map units. The *dot-grid method* uses a transparent sheet or card on which dots are evenly spaced vertically and horizontally. Each dot on the grid represents a small square, which has a unit area. The transparent sheet is placed over the map and the dots in each delineation are counted. Dots that fall on the boundary of a delineation are alternately counted. The dots in each delineation are summed for the map unit.

The land area represented by each dot can be calculated on the basis of the map scale and the spacing of the dots. Less extensively used are grids that have a network of small squares instead of dots. The squares that fall within a delineation are easily counted. Squares that fall on a boundary of a delineation are averaged during counting. The averaging depends on the judgment of the person who is counting. If it is carefully done, the use of squares can result in somewhat greater accuracy than the use of dots. The former method is more time consuming.

The dot-grid method is simple, inexpensive, efficient, and convenient. For these reasons, it is the method most commonly used in field offices. A short-coming of the dot-grid method is that it is not well adapted where there are long, narrow delineations on the map. It is sufficiently accurate for most purposes, however, because the land areas for the map units tend to be averaged if large areas, that is, entire field sheets, are measured. The *electronic area calculator* is an alternative method to the dot-grid method in that it electronically counts squares on a grid. By using an appropriate grid to fit the desired map scale and a wired pencil assembly to trace the map unit boundary, area can be determined easily from a numerical display. This method compares closely in accuracy to the dot-grid method but is much quicker and more convenient. It is initially much more expensive than the dot-grid method.

The *planimeter* is an instrument used to measure area by measuring the length of the boundary of the delineation. This is done by following the outline of the delineation with a tracer. The value indicated on the planimeter is converted to land area by using an appropriate conversion factor related to map scale. The use of the planimeter is an accurate method to measure maps, but it is very slow and tedious. Accuracy depends on the skill and patience of the operator and on the care taken to convert measured value to land areas.

Computer-based digitizing systems have the capability for measuring the area of map units. These systems are not only very accurate but serve as an excellent final check for errors on field sheets—open boundaries, areas without symbols, and the like. They can replace color checks and other methods of checking field sheets.

Cultural Features

The various mapping agencies of the United States Government have agreed on standard symbols for most cultural and natural ground features that are commonly identified on maps. Most of the symbols used on soil maps follow these standards. Some soil maps show special features that are not included in the standard list. The symbols for these must be compatible with symbols used by other mapping agencies. Different symbols are not used for the same feature, nor is the same symbol used for different features.

Conventional and special map symbols must be functional and readily identifiable on the map.

Conventional signs and symbols used in soil mapping are shown on figure 4-7. Some of these are described in the paragraphs that follow.

Boundaries of cultural features are shown on soil maps by standard conventional symbols. These include the boundaries of nations, states, counties or parishes, minor civil divisions, reservations (including Federal or State parks and forests), land grants, parks, and cemeteries.

U.S. Geological Survey (USGS) maps are the primary source of cultural boundaries. Where USGS maps are not available or must be supplemented, local sources are used. County or State assessors, planning and zoning officials, and reservation superintendents are authoritative sources. Boundary monuments are located in the field and boundaries are plotted during soil mapping only where boundary location cannot be plotted accurately from references. Boundaries are verified as a precaution against errors.

Where cultural boundaries of different classes coincide, the symbol of the major subdivision is used, for example where a State boundary coincides with a county boundary the State boundary has priority. Where a boundary obviously follows a stream or road for a short distance, the boundary symbol may be omitted. In some places, the road or stream may be labeled for clarity: "Road is county boundary" or "State boundary is center line of stream."

Township and range numbers are shown along the margins of field sheets for all lands that have been sectionized. Section lines are not shown. In some surveys all sections corners are shown; in others, only those that have been located are shown. In a published soil survey, section numbers are printed in the approximate center of each section. Published topographic quadrangle maps show the land grid, though some old ones may need correction. Soil scientists working in an area should be familiar with the local land survey system and its intricacies.

Cemeteries are outlined to scale on field sheets using dashed lines. The name is usually placed within the outline of a large cemetery and outside a smaller one, although the smallest cemeteries are usually indicated by a cross and not named. A feature such as a road or stream may serve as a boundary for a cemetery.

The identification of *airports* and *landing fields* is optional on field sheets. Boundaries of large municipal, commercial, and military airports and landing fields are shown by the symbol for a reservation. The runway pattern is not delineated if it is apparent on the aerial photograph. Small airfields can be shown by a dashed line symbol similar to that used for a cemetery, or the symbol for a "located object" can be used and labeled. Each airfield that is identified is labeled by its proper name or "airfield," if the name is not known.

Roads are identified on soil survey field sheets by symbol or name. In towns and cities only major roads are identified. Standard emblems are used to designate interstate, Federal, State, and other roads. Route numbers are placed in the emblems. If roads are shown, a simple and explicit classification is used.

The mapping of *trails* depends on their importance for proper map orientation and the help they will provide in locating specific areas on the map. In sparsely settled areas having few readily observable landmarks, important trails are shown and named. In more densely populated areas where roads are common, trails generally are not shown.

Railroads are shown on field sheets by conventional symbols. They may be labeled "railroad" or by the name of the line. Electric trolley lines both in urban areas and beyond city limits are shown by the standard railroad symbol and designated by operating name and type. In large railroad yards with parallel spur tracks and switches and sidings alongside single tracks, only the main track is shown.

Pipelines are shown on soil maps if they might be important as landmarks. A pipeline crossing a remote section of a survey area may be important. A similar pipeline in a populated area may be difficult to locate accurately and may have little value as a landmark. If shown, a pipeline must be accurately located.

Trunk *power-transmission* power lines are normally not shown on field sheets unless they have value as landmarks. They must be individually evaluated. Lateral distribution systems are not shown. The symbol for power-transmission lines, if used, begins and terminates at towns, power stations, and survey area boundaries.

Levees are indicated by short ticks. If a road or railroad is on the levee, the ticks extend from both sides of the road or railroad symbol.

Large permanent *dams* are shown to scale on field sheets. Thin lines are used to delineate the base of the dam. Smaller dams are indicated by single, heavy lines. A road following the top of a dam is shown in its correct place, and the road line on the upstream side is thickened to represent the dam. A dam symbol is inked to its scaled length. Important dams are named.

Permanent buildings.—rural dwellings, public buildings, and farm homes—are shown on most published soil maps but are optional. In some areas, buildings are constructed so rapidly that the map is out of date before it can be published. In such areas, omitting symbols for all buildings other than churches and schools is best. In most soil surveys, churches and schools are shown on the published map and may be named.

Symbols for individual houses are commonly not shown in urban areas. Prominent landmark buildings—large schools and large churches—may be shown, but they are not drawn to scale and are identified by the conventional symbols.

The cross or pennant of a church or school symbol is oriented at right angles to a nearby roadway. A building used as both a school and a church is marked by the school symbol. If churches or schools are omitted from large urban area but mapped in rural areas, the notation "omitted in urban areas" is made on the legend of conventional symbols.

Open pits, mines, and *quarries* smaller than the minimum area for delineation are shown only by conventional symbols. Larger areas are delineated, classified, and correlated as kinds of soil or miscellaneous areas.

Producing *oil* and *gas wells* may be shown. Where the number of wells is so large that the symbols are closely spaced on the map, the approximate outline of the field may be shown by dashed lines and the delineated area identified as "oil field" or "gas field" without the conventional symbol.

Streams and *rivers* are shown on the field sheets, and perennial and intermittent streams are clearly differentiated. The pattern of drainage and the classification of the drainage must be complete. If the main drainage courses are identified by stereoscopic study of aerial photographs, the lines must be confirmed and the drainage classified in the field. Most distinct drainage courses more than 1 cm long on the field sheets are shown. Drainage courses are mapped to scale if wide enough to be shown legibly or by single lines if narrow.

A *perennial stream* is one in which water flows constantly except during periods of unusual drought. That a stream is perennial must be verified, especially in semiarid and arid regions where the water in streams and waterholes is vitally important.

Mapping large rivers that change course and width from time to time is difficult. The shorelines shown on a soil map generally mark the areas covered with water for so long that little or no vegetation grows during low water and unvegetated riverwash persists from year to year. Areas that are covered by flood water for only short periods are excluded. Areas that are uncovered only during very low water stages are included.

The level of river stages varies widely, depending on characteristics of the river in relation to the climate of its watershed and other factors. Where the flow of rivers, though active for brief periods, dwindles or ceases altogether for many months, the normal stage is very low. Thus rivers, such as the Platte and much of the Rio Grande, are normally braided, and the boundaries of the river are usually placed at the outer limits of the area of braided channels. Unstabilized sediment that is washed and rewashed and supports little or no vegetation but persists from year to year may be identified as riverwash. Areas within a flood plain that can support vegetation are shown as soil.

Some streams, especially in areas underlain by limestone, enter abruptly into caverns and may flow for long distances through subterranean channels. The points where the streams enter and emerge are located accurately, but only the surface drainage is shown.

An *intermittent stream* is dry each year for extended periods, usually for more than three months. In arid and semiarid regions especially, intermittent streams are distinguished from perennial streams because they are not reliable sources of water.

Poorly defined water courses are not shown. Aggraded flats or valley floors without well-defined stream channels or scars are shown as soil.

Canals and *ditches*, whether for navigation, irrigation, or drainage, are plotted to scale if they are wide enough. Otherwise they are shown by the single-line symbol. Arrows indicate the direction of flow. Generally, both the main ditches and important laterals of irrigation systems are shown. Large canals and ditches are named on the field sheets if they have names. On the map, canals and ditches must be distinguishable from roads.

Lakes, *ponds*, and *reservations* are delineated to scale on field sheets. The boundary marks the normal water level, which may not be the shoreline observed and recorded at the time of the survey. Normal water level may be marked by a line of permanent land vegetation, but many lakes are bounded by wave-washed beaches above the normal water level. Many reservoirs are bounded by areas that are submerged when the water level is high. The shore line that is evident on aerial photographs may be used to delineate the normal stage of a lake, pond, or reservoir. If a high water level other than wave-washed beaches can be identified, it is shown on the map by the intermittent water symbol and is identified. The area between high water level and normal water level can be defined as a soil map unit if the area warrants it. The intermittent water symbol is not used in these areas. The intermittent water cover is described in the map unit description.

Reservoirs surrounded by an impounding structure are outlined. Some reservoirs have flood-pool lines that are determined from available sources. They are shown on the map by a dashed line and given an appropriate label, such as "approximate flood-pool line."

The shoreline of an island is determined at the same water stage as the adjoining mainland shoreline. Islands exposed at a lower stage are not shown.

Tidal shorelines present special problems. The mean high tide level (determined excluding the semimonthly highest tides) can be used where the land rises to elevations well above high tide within a short distance from the shore. Where broad marshes mark the transition from sea to land, the shoreline is the outer boundary of the area that supports plants. The soil boundaries extend to that line.

The shoreline of a body of water is not broken for wharves, piers, and similar structures that may be built over the water. Seawalls and retaining walls that are part of a shoreline are shown as the shoreline.

Intermittent lakes are shown on the field sheets as kinds of soil or miscellaneous areas. The dashed line symbol shows the area covered by water part of the year.

Marshes and *swamps* are mapped as soil unless they are too small to be delineated. If too small, they are shown by the conventional marsh or swamp symbol.

Springs are shown on the soil map if they are important in the area. Springs of all kinds are shown in arid and semiarid regions. In humid regions, only large and dependable springs are shown. Some springs have names, which may be printed on the soil map. In arid regions, intermittent springs or springs that have salty or otherwise impotable water are so identified by notes on the map. Walled-in springs are shown by circles, like those for wells. A spring that is a source of a stream is shown by a circle where the stream symbol starts.

Artesian wells and wells for irrigation are shown on soil maps where they are important sources of water, as in arid and semiarid regions. Artesian wells are designated by a conventional symbol, whether or not they flow at the surface. In regions of few wells, all are shown; but in thickly settled areas that have many nonflowing artesian wells, they can be explained in the report without being shown on the map.

A *wet spot* is an area of wet soil that is too small to delineate. It is usually somewhat poorly drained or wetter and at least one drainage class wetter than the soil around it. Wet spot symbols are not placed within areas that are mapped as a wet soil.

Special symbols are used to identify small areas of various kinds of soil, miscellaneous areas, and special soil features. These are commonly used for areas that are too small to delineate but large enough to significantly influence use and management. If a specific kind of area is shown by special symbols, all such areas of that land are shown; the symbols are not to be used haphazardly. The symbols must be defined in terms of the kinds and size of areas each symbol represents.

In some places, the pattern of mappable areas is so complex that symbols and leaders clutter the map. Special symbols used with moderation reduce the congestion of lines and symbols, although many special symbols in a small area reduce legibility. It may be preferable to map as complexes many areas of intricately associated kinds of soil.

Special symbols show relief features that are too small to show as map units; for example, *bedrock escarpements*, *short steep slopes*, and *gullies*. Natural depressions or sinks such as those common to limestone areas, may be shown by the *depression* or *sink symbol*. Small areas of *rock outcrop* in an area of otherwise deep soil are obstacles to tillage and should be shown. In addition, small areas of *saline* soil and *very stony* soil, in areas otherwise suitable for crops should be shown. Special symbols are used for small areas of some kinds of soil that contrast sharply with surrounding soils in their management needs or productivity, even though they are suited to the same uses. Small areas of *gravelly* soil in gravel-free areas, *sand spots* in areas of finer textured soil, and small areas of severely or moderately eroded soil in areas of noneroded soil are examples.

Equipment

The efficient operation of a soil survey requires the use of certain kinds of equipment, some easy, some difficult to obtain. There are three major kinds of needs: Tools to examine the soil profile and soil testing, measuring and recording devices for mapping, and transportation vehicles. Some of these are described in the following section.

Tools for Examining the Soil

A soil scientist examines the soil often in the course of mapping. Examination of both horizontal and vertical variations is essential. The most commonly used tools are spades and soil augers. Backhoes, spades, and shovels are used to expose larger soil sections for examinations, sampling, and photography. Augers are used in most areas for routine mapping. In some areas, however, a spade is used to examine the soil. In soils free of rock fragments, probes provide samples that are quick and relatively easy to obtain. Where a probe or auger is regularly used for examining the soil, some profiles need to be exposed in a pit and examined as a check. Power equipment is often used to save time and effort. Various small instruments can also be used to examine the soil.

Spades, shovels, picks, and bars.—Especially after a preliminary excavation has been made, a flat-bladed, square- pointed spade is most convenient for collecting samples. The best spade for ordinary use in mapping is a tile spade or a post-hole spade that has been modified by cutting off the sharp corners. A tile spade has a rounded point and tapers at the end. It is superior to a post-hole spade for stony and gravelly soils. The blades of post-hole and tile spades are commonly 30 to 45 cm in length. Where deep holes are required, a long-handled spoon-type shovel is useful.

A heavy crowbar and/or pick may be needed to penetrate dry, cemented, or compact layers. A mattock is especially useful for making holes in soils that are hard, dry, stony, or gravelly. A small army-issue trenching pick will serve satisfactorily in some soils, but commonly the heavier conventional mattock with a long handle is better. One end of the mattock is pointed and the other is a chisel. For moist soils and those containing many woody roots, the chisel point is useful; for dry soils, the sharp point is more effective. A geologist's hammer, one end of which can be used as a pick, is also useful in examining rocks and the soil in cuts.

A post-hole digger is useful in removing deep soil material for examination. A digger is heavy and is used mainly for sampling at the bottom of pits where digging is difficult. It removes the soil with less disturbance of structure than most kinds of augers.

Augers.—The screw, or worm, soil auger is essentially like a wood auger and ranges from about 2 1/2 to 4 cm in diameter (fig. 4-10a). The worm part is about 15 cm in length, and the distance between flanges is about the same as the diameter. If the distance between flanges is less, removing the soil with the thumb is difficult. In clayey soils, a bit of 2 1/2 cm may work better than the larger ones. The shaft is commonly 100 to 150 cm in length. Extra lengths can be added for deep boring. The bit will become tapered as it wears, therefore, it should be replaceable. A scale can be marked on the shaft of the auger to measure depth to the tip.

Screw augers made especially for examining soils are available, but they can also be made from a wood auger bit and lengths of pipe. The auger bit is welded to a steel rod or iron pipe with a crosspiece at the top for a handle.

A screw auger is easily carried. It can be used to examine gravelly or stony soils and to bore holes rapidly. It cannot be used in dry or sandy soil because the soil material will not adhere to the bit. It is difficult to pull from the bored hole. The extracted soil material is disturbed more by a screw auger than by other augers and probes.

Several kinds of barrel augers are used. Barrel augers are known as post-hole augers, bucket augers, orchard augers, core augers, and various other names. They have a cylinder, or barrel, to hold the soil, which is forced into the barrel by cutting lips at the lower end (fig. 4-10b). The upper end of the cylinder is attached to a length of pipe with a crosspiece for turning at the top. Although both ends of the cylinder are open, the soil generally packs so that it stays in place while the auger is removed from the hole. A few taps of the cylinder on the ground or on a board will loosen the soil for removal. Barrel augers with special closed cutting blades are available for use in(cr)-1(ew)-2(au)-14(g)(lt to)2(s)-1dsa- [0(t)- nn2(ps)-1(a)4(o( )]TJ 0 T(cr)-1(ew)-2(au)-14(g)10(g)10(c) more slowly than screw augers or probes. Generally, they are more bulky to carry. They are easy to pull from the hole. Tips wear excessively if not made of hardened steel. Where animals are grazing, the holes must be filled.

FIGURE 4-10

Soil augers and tubes: A, screw or worm auger; B, barrel auger; C, sampling tube; D, "Dutch" "mud" auger; E, peat sampler.

The Dutch auger is a modified barrel auger having two connected straps with lips (fig. 4-10d). The cylinder is about 5 to 10 cm in diameter. The cutting blades are so constructed that the soil is loosened and forced into the cylinder of the auger as it cuts into the soil. The Dutch mud auger works well in moist or wet soils of moderately fine or fine texture. This auger works poorly in other moist or wet soils and in all dry soil.

Soil augers are simple in design and somewhat crude in appearance, but considerable skill is required to use them effectively and safely. They must be pulled from the soil by using a technique that puts stress on the leg muscles, rather than the back muscles, to avoid serious back injury. Twisting the auger firmly while pulling takes advantage of the inclined plane of the screw to break the soil loose. A pair of pipe wrenches is needed to add and remove lengths of shafts and bits.

Examinations of deep deposits of peat are made with special tubelike samplers. A peat sampler designed by the Macaulay Institute for Soil Research, Aberdeen, Scotland, takes a relatively undisturbed volume that can be used for measurement of bulk density. The Davis peat sampler, consists of 10 or more sections of steel rods, each 60 to 120 cm in length, and a cylinder of brass or Duralumin, approximately 35-cm long with an inside diameter of about 1.9 cm (fig. 4-10e). The cylinder has a plunger, cone-shaped, at the lower end and a spring catch near the upper end. The sampler is pressed into the peat until the desired depth for taking the sample is needed. Then the spring catch is released, allowing the plunger to be withdrawn from the cylinder. With the plunger withdrawn, the cylinder is filled by forcing it further downward. The cylinder protects the sample from contamination and preserves its structure when the sample is removed. With this instrument, one can avoid the error of thinking that firm bottom has been hit when actually a buried log is encountered.

Probes.—Probes consist of a small-bore tube that has a tempered sharp cutting edge slightly smaller in bore but larger in outside diameter than the barrel (fig. 4-10). Approximately one-third of the tube is cut away above the cutting edges so that the soil can be observed and removed. Probes are about 2.5 cm in diameter and about 20 to 40 cm in length. The tube is attached to a shaft with a "T" handle at the opposite end. Shaft length can be varied by adding or removing sections. Probes can be used to examine the soil to a depth of 2 meters. A pedal that is attached to the shaft is available to allow the operator to apply body weight. Some workers carry rubber or plastic mallets to drive the tube into the soil. A pair of pipe wrenches is needed to add and remove lengths of shaft.

Probes work well in moist, medium textured soils that are free of gravel, stones, and dense layers. Under these conditions, the soil can be examined faster than with an auger. Probes are very difficult to use in dry, dense, or poorly graded soil, and in soil containing gravel or stones. Probes disturb the soil less than augers, but they retrieve less soil for examination. Probes are light and easily carried, and they pull from the hole more easily than screw augers. Often a special punch or dowel must be used to clear the tube. Use of a soil probe is the fastest method to collect samples of surface layers for analysis. Probes used with power equipment have wide applications in soil surveys (fig. 4-11 (no longer available)).

Power equipment.—Power equipment is used for rapid excavation or for extracting cores and samples rapidly and from depths that are difficult to reach with hand tools. The use of power equipment results in large savings in time and permits deeper and larger excavations with better exposure of the various horizons than can be attained with hand tools. Not all sites, however, are accessible to power equipment. Most of this equipment is powered by the motor of the tractor or truck on which the equipment is mounted, although some of the heavier types have separate power units.

A backhoe (fig. 4-12 (no longer available)) is used to expose vertical sections of soil. The width of the bucket, or shovel, ranges from 30 centimeters on the smaller models to more than 75 cm on the larger ones. Small backhoes are available that mount on the back of small trucks or on small self-propelled vehicles. The larger backhoes are mounted on tractors. Excavations can be made rapidly to depths of 2 or 3 m performing in a matter of minutes a task that would take two people most of a day. Backhoes can be used effectively in gravelly and stony soils as well as in soils that are stone-free. They ensure good horizontal and vertical exposure of the soil profile.

Backhoes have limitations. Maintenance costs are high, and time must be taken for maintenance. Operators must be trained, and safety standards must be met. Some property owners do not want large equipment on their property. There is a tendency to dig pits so deep

FIGURE 4-14

A hydraulically mounted sampling tube mounted on a pickup truck. The open-faced tube is in place. Hydraulic controls are at the right.

that site walls are weakened. This practice is dangerous for anyone in the pit. Rental costs for backhoes are high in the areas where machines are available for rent.

Power augers are commonly mounted on a small truck and are powered by the engine of the truck. Some have independent power plants and can be mounted on a trailer. The auger can be raised to permit soil to be taken from the bit for examination and can be reinserted in the hole for continued sampling. The bits are 5 cm to more than 15 cm in diameter and generally are threaded over lengths of 50 cm or more. Some augers, such as that in figure 4-13 (no longer available), are threaded their entire length and have extensions that permit sampling to depths of a few meters. Power augers can be equipped with barrel-type bits. The barrels are usually larger and heavier than those on hand augers. Most power barrel augers have a cylinder that can be opened for removing the sample.

Power-operated probes (figs. 4-11 (no longer available) and 4-14) are used in moist soils that have few stones. They are usually mounted on a truck and are forced into the soil by hydraulic drivers that are powered by the engine of the truck and act against the weight of the truck and its load. The tubes are usually 2.5 to 10 cm in diameter. They can effectively remove undisturbed cores of soil to a depth of 2 m or more. The top of the tube can be taken off. The tube is open on one side, which permits removal of the core. Power probes are especially useful in moist stone-free soil material, such as loess. They function poorly in dry soils and in soils having cemented layers.

Equipment is available that anchors the truck to the ground by means of a screw. Anchoring allows undisturbed cores to be taken at a greater depth and over a larger range of soil conditions.

Power equipment for extracting samples for examination or analysis is necessary in soil surveys that require systematic sampling of deep layers, as in many areas where landscapes have low predictive value. In dry areas, deep layers that have no influence on present vegetation can be very important to the success of irrigation farming. Power equipment has made surveys of such areas much more accurate and much less physically demanding on fieldworkers.

Power augers and probes have limitations. Generally, holes can be bored or probed only when the truck is level. If the truck is not equipped with four-wheel drive, off-road operation in wet areas is curtailed. Fences further restrict off-road movement. Equipment and maintenance costs of power augers and probes are high. Operators must be trained and safety standards met. Power augers mix the soil so that depths to different layers cannot be measured accurately.

Dense soils and soils that contain large amounts of rock fragments are difficult to examine. Electrically powered jackhammers that quickly loosen compact or skeletal material are available. The loosened material can be thrown from the pit with a shovel. The jackhammers are similar to those used in street repair. A chisel bit is used. The power source is the truck generator or an independent gasoline-powered generator. Use of jackhammers is limited to areas that can be reached by truck. The initial cost is high.

The scheduling of power equipment is important to ensure maximum use of it while the equipment is available and weather and soil-moisture conditions are advantageous.

Small implements.—Many kinds of small implements are used for examining soil. Although personal preferences may influence choices, certain general types of implements are essential almost everywhere.

A large knife is the most commonly used small tool for probing and digging in an exposed profile. A sheath knife having a blade about 10 to 15 cm in length and 2 1/2 to 5 cm in width—the kind available for hunting or camping—can be used for probing the soil, for cutting through peds to observe the interior, for removing small amounts of material, for cutting roots, for scraping the vertical or horizontal sections of the pedon, and for a variety of other purposes. Trowels, spatulas, putty knives, and other small instruments are used similarly.

A geologist's or mason's hammer is useful, especially for breaking cemented layers and examining rock fragments and very strongly cemented nodules. The chisel-shaped end of the head can also be used for digging unconsolidated material.

Various small instruments for measurement and observation are essential. A scale for measuring is indispensable. Graduated steel tapes that retract into a small case are most useful. A hand lens is very important. A 10X lens is most common, but lenses having magnifications that range from 4X to more than 50X are used. Some, mounted in a pen-sized tube, have high magnification but a small field. Some of these have battery-powered lights for illuminating the sample. A pocket magnet for separating magnetic material is useful in some areas. A soil thermometer is needed by most field scientists. Those having a metal probe and a dial on which the temperature is read are especially suitable for use in soil.

A grid for area measurements or for point counts of features like stones is an important part of the kit of a soil scientist. The grid may be simply a piece of wire mesh with the spacing of wires chosen to fit the scale at which measurements are to be made. A hand tally or counter is useful for point counts; it is also useful for recording paces in measuring distance. Standard color charts and standard charts for the estimation of proportionate area are also necessary components of the kit.

Mapping Equipment

Various small pieces of equipment and instruments are used in mapping. The choices of fieldworkers vary, but certain kinds of equipment are essential.

Various kinds of metal or wood clipboards or folders are used for holding the map (fig. 4-15). Some surveyors use an aluminum folder with a spring clip and a covering flap that is hinged at one edge. If the field sheets are large, a rotary map cylinder is useful.

FIGURE 4-15

A hand-help map board with aerial photo base map in place.

The part of the map being used is exposed on the board, and the unused part is rolled into a cylinder attached to the edge of the board. The cylinder protects the unused part of the map and provides a work surface. Some field scientists make these map holders to suit their own needs (fig. 4-16 (no longer available)).

The use of aerial photographs as mapping bases has almost eliminated the need for compasses for finding bearings. In areas where keeping located is difficult, a compass must be used to orient the map and to take bearings from which the soil scientist can plot location. A traverse board consists of a map board that has a compass attached at one edge and that rotates on a tripod.

In mountainous areas, an altimeter can be used to determine elevation and establish location relative to contours on topographic maps. Altimeters measure altitude by measuring changes in barometric pressure as related to elevation and must be adjusted at a point of known elevation to the barometric pressure at the time.

An instrument is needed for measuring slope gradient. The Abney hand level (fig. 4-17) is commonly used. For convenience, the scale is graduated in percent of slope or in both percentage and degrees. This instrument consists of a small spirit bubble level pivoted above a graduated arc and is operated by rotating the level until the bubble, visible through the eyepiece by means of mirrors, indicates that the level is horizontal. The barrel of the level is sighted parallel to the soil surface. The gradient is read directly from the graduated arc.

Clinometers are used in some places to measure slope gradient. In a clinometer, a weighted string swings across a graduated arc. Clinometers are lighter in weight, more convenient to carry, and slightly faster to use than an Abney level.

FIGURE 4-17

Abney hand level with case.

A scale for measuring distances on the map is needed. A supply of pencils that have different degrees of hardness should be carried. The hardness chosen is determined by temperature and humidity and by the material of the mapping base. If aerial photographs are used, the pencils should leave a fine dark line that does not smudge easily on handling, but it should not be hard enough to cut the emulsion. Because soil boundaries must be adjusted and the symbols changed frequently, the pencils should make marks that can be erased without smudging and without damaging the mapping base.

Transportation

Field operations of the soil survey require transporting workers, equipment, supplies, and soil samples. Vehicles are provided to the soil survey party for their daily operations. The time spent by soil scientists traveling to and from the field is lengthy and mainly unproductive. Enough vehicles are provided to keep travel time as short as possible.

Additional equipment used for special purposes or for short periods is usually rented or supplied as needed. A passenger van, for example, may be furnished by one of the agencies during a field review. Aircraft may be rented to visit areas not readily reached by ground transport.

The uses of vehicles vary widely from one area to another. In some areas, travel is mainly on roads; in other areas, vehicles must be used to travel across country during mapping or to reach remote sites for soil studies. Some vehicles must carry power equipment or pull trailers. All vehicles that are provided for use should carry workers efficiently and in comfort and safety, hold the equipment that is used regularly, have some reserve capacity to accommodate an extra load, and protect workers and equipment from adverse weather.

In many areas, pickup trucks are desirable. Trucks are available with optional equipment that may be useful in some areas. Optional equipment includes four-speed transmissions for mountainous and off-road travel; four-wheel drive for off-road travel under adverse conditions; high clearance for travel over rough or stony areas; oversize radiators for use in hot climates, for use where the truck engine will be idled for long periods, or for use with power probes, augers, or winches powered by the truck engine; special tires and wheels for unusual wet, rocky, sandy conditions; and special bodies or truck beds for mounting and storing special equipment (fig. 4-11). In some remote areas, vehicles are equipped with two-way radios. The various kinds of optional equipment have various disadvantages and limitations such as increased initial cost, increased operating and maintenance cost, increased downtime for the truck, difficulty in obtaining replacement parts, a decrease in the truck's handling qualities, and a decrease in road speed.

In areas with good roads and little off-road travel is required, passenger vehicles are adequate. Passenger vehicles also are used to transport groups for field reviews.

Specialized vehicles are necessary in some areas. Tracked vehicles and all-terrain vehicles (ATVs) may be needed in very rugged areas (fig. 4-18) Marsh buggies with large buoyant tires and airboats are used in swamps and marshes. Snowmobiles provide access in winter to some northern swamps where travel is impossible or impractical in other seasons. Trail bikes or ATVs

FIGURE 4-18

An example of one type of all-terrain vehicle used for soil survey operations in areas inaccessible to ordinary wheeled vehicles.

can be used in areas that could otherwise be reached only by walking. Specialized vehicles must be reliable in relatively inaccessible areas. The equipment must be transported to the use area. Costs of buying or renting the equipment, maintaining it, and training operators can be high.

Time is needed for transport, maintenance, and training. Some kinds of equipment are hazardous to operate. Sensitive ecosystems may be damaged by the equipment.

Aircraft, particularly helicopters, are used in some soil surveys to transport workers and equipment and to provide broad views of landscape and vegetation. Aircraft are useful for photographing landscapes, soil patterns, and land use. Availability, cost, and lack of conventional landing sites are the main limitations.